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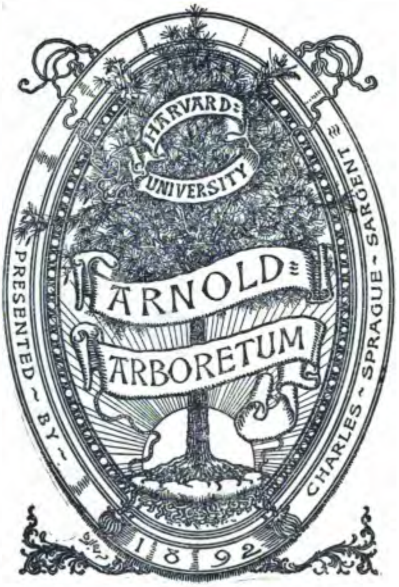

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 102.

B. T. GALLOWAY, *Chief of Bureau.*

MISCELLANEOUS PAPERS.

I. SUMMARY OF RECENT INVESTIGATIONS OF THE VALUE OF CACTI AS STOCK FOOD.

By DAVID GRIFFITHS, *Assistant Agrostologist,*
and R. F. HARE, *Chemist, New Mexico College of Agriculture and Mechanic Arts.*

II. A SUCCESSFUL DAIRY FARM.

By L. G. DODGE, *Scientific Assistant.*

III. PLANNING A CROPPING SYSTEM.

By W. J. SPILLMAN, *Agriculturist.*

IV. THE APPLICATION OF VEGETATIVE PROPAGATION TO LEGUMINOUS FORAGE PLANTS.

By J. M. WESTGATE, *Assistant Agrostologist,*
and GEORGE W. OLIVER, *Plant Propagator.*

V. THE CONTROL OF TEXAS ROOT-ROT OF COTTON.

By C. L. SHEAR, *Pathologist,*
and GEORGE F. MILES, *Scientific Assistant.*

VI. THE HISTORY OF THE COWPEA AND ITS INTRODUCTION INTO AMERICA.

By W. F. WIGHT, *Assistant Botanist.*

VII. A NEW METHOD FOR THE DETERMINATION OF NICOTINE IN TOBACCO.

By WIGHTMAN W. GARNER, *Scientific Assistant.*

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MISCELLANEOUS PAPERS.

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SUMMARY OF RECENT INVESTIGATIONS OF THE VALUE OF CACTI AS STOCK FOOD.[a]

By DAVID GRIFFITHS, *Assistant Agrostologist, Farm Management Investigations, Bureau of Plant Industry*, and R. F. HARE, *Chemist, New Mexico College of Agriculture and Mechanic Arts.*

INTRODUCTION.

In connection with introductions, the improvement of species, and a general study of the economic relationships of native and introduced species of cacti the authors have jointly undertaken a somewhat critical comparison of the species of this group from a forage standpoint. In order to make the chemical work worth while it has been necessary to put the characterizations of the different forms and species in such condition that they are recognizable to others. This could only be done by the use of copious notes in connection with each, for names are of uncertain meaning and in many cases will be of uncertain significance in this group of plants for a long time to come. The chemical side of the investigations seems to be essential, for when these studies were begun there was but little literature dealng with the cacti from a forage standpoint.

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[a] In two publications of the United States Department of Agriculture (Bulletin No. 74 of the Bureau of Plant Industry and Bulletin No. 91 of the Bureau of Animal Industry) the value of the cacti as forage plants has been demonstrated. Since these plants are known to possess important economic value more knowledge concerning hem is desirable. As a basis for future investigations, the Bureau of Plant Industry and the Agricultural Experiment Station of New Mexico have collected specimens of these plants and their fruits from a wide area, from which a large number of chemical analyses have been made. The results are detailed in the following pages, which contain 187 fodder analyses and 26 complete ash analyses. The territory from which he material was collected extends from central Texas to California and southward to he central plateau of Mexico.

Attention is called to the fact that the apparent high content of fats and protein in he fruit of certain species is due to the large amount of these classes of nutrients found n the seed. As these seeds are surrounded by a dense layer of wholly indigestible issue, the high content of ether extract and protein is misleading. The analyses how that the fodder value of the fruit of cholla (*Opuntia fulgida*) especially is little more than that of the stems. It will be seen that in chemical composition the different orms of cactus compare favorably with ordinary green fodders and root crops.

There are many points of special interest in connection with the ash analyses, paricularly the high content of potash, magnesium, and calcium. Although the cane cacti show a relatively higher food value, practical considerations relating to growth and ease of propagation render them of less value than the prickly pear, except in certain limited localities where they are especially abundant.—W. J. SPILLMAN, *Agriculturist in Charge of Farm Management Investigations.*

The investigations have been conducted in cooperation between the Office of Farm Management Investigations of the Bureau of Plant Industry and the Agricultural Experiment Station of New Mexico for the purpose of determining, if possible, the extent of variation and the nature of the food constituents of the different species which are likely to be utilized as food for stock. The plants are grouped under three general headings—prickly pears, cane cacti, and miscellaneous—the first group being by far the most important, though the second is largely utilized in sections where its different representatives grow. Three or four members of this group have been fed to stock with more or less success. The third group consists of miscellaneous species from other cactus genera, which on the whole are but little utilized as stock feed, although it is clearly shown that some of the species have been fed in rare instances. The interest in this group is largely a matter of comparison with the others.

Details of the investigations are published in Bulletin No. 60 of the Agricultural Experiment Station of New Mexico.

THE SAMPLES OF CACTI ANALYZED.

Considerable importance is attached to the method of sampling, it being recognized that uniform samples of such succulent and variable plants are difficult to secure. It appeared more logical, therefore, to describe the samples in such a way as to give other investigators and the reader an accurate idea of the portion of the plant used in the chemical analysis. The sample is indicated by a formula—for example (2–1–4–3–5) 3—in which the left-hand figure indicates the number of terminal joints, the second number from the left the number of joints next to the terminal joint, and so on, the figure outside of the parentheses indicating the number of plants from which the sample was collected. All samples were forwarded to the laboratory in tin cans from which a minimum of evaporation took place. They were prepared by first being sliced open, so as to expose a maximum of cut surface, and dried by artificial heat at a temperature of not more than 70° C. The spines were then singed off by a small flame of complete combustion, care being taken neither to deposit combustion products upon nor injure the specimens. In the analyses the methods of the Association of Official Agricultural Chemists were followed, with the exception of a few modifications in the determination of certain ash constituents.

WATER CONTENT.

A collection of samples for chemical analysis was begun in 1904, and a fairly complete set was secured during that year; but, owing to the uncertainty due to the analysis of single samples, these were nearly all duplicated in 1905, in most cases from the same localities.

Fortunately there was a great difference between the rainfall during the months from January to March of 1904 and 1905. The effect upon the water content of the plants is fairly well illustrated in the different tables of analyses, although no special effort was made to collect the samples for the purpose of showing this feature in detail. There are some apparent exceptions to the rule that the samples collected in 1904 contain more water than those collected in 1905; but this may be accounted for in some cases by the difference in the portions of plant collected or in other cases possibly by local conditions. The amount of water in the different samples analyzed varied from 60.99 to 95.5 per cent. The miscellaneous group is relatively more succulent than either of the other two, the average amount of water being 87.88 per cent, while the prickly pears averaged 84.26 per cent and the cane cacti 78.47 per cent. As a rule, the fruit contained more water than the stems and the younger growth more than the older.

The difference in the species in the field during a dry and a wet season is very marked, and even prickly pear has its limit of drought endurance. Experience in southern Texas demonstrates that it is much reduced in value during very prolonged dry seasons, for it becomes tough and leathery. "Fat pear" is largely the result of distention of the tissues by water. Some species, *Opuntia fulgida* especially, when a favorable moist season follows an exceptionally dry one, will absorb so much water that the fruits and young joints become ruptured by the excessive turgidity, and this often occurs with the fruit of nopal camueso and other cultivated Mexican species.

ASH CONTENT.

Plants grown in the arid and semiarid Southwest, where there is an abundance of soluble salts in the soil, are found to contain more ash than those grown in regions of frequent rainfall. The cacti are certainly no exceptions to this rule. The average ash in the air-dried stems and fruits of the prickly pears analyzed amounts to 18.25 per cent, for the cane cacti 15.50 per cent, and for the miscellaneous group 13.54 per cent, one sample running as high in ash as 33.8 per cent of the air-dried substance. These averages would be still higher if they did not include the ash of fruits, which always contain less ash than the stems. The average ash in the air-dried fruits of the prickly pears, for instance, is 13.21 per cent, which is 5.4 per cent less than is contained in an average of both stems and fruits of this group and 6.35 per cent less than is in the stems alone. It is the seed which is especially low in ash, the fleshy portion resembling the stem more closely so far as its ash content is concerned. This is brought out very forcibly in samples Nos. 8022*a* and 8022*b*, the former being the fleshy portion and the latter the seed of *Opuntia phaeacantha.* The fleshy portion contained 25.60 per cent of ash, while the seed contained only 1.77 per cent.

The elements of the ash are present in about the same proportion as in the ash of other plants, except potassium, magnesium, and calcium, which are found in large amounts. It is probably the presence of these salts, coupled with the high water content, that causes cattle to scour when fed on an exclusive roughage ration of these plants.

In the following table there is given a complete analysis of the ash of a few of the samples, together with the results of the analysis of a composite sample, and an average of all the ash analyses made. Complete ash analyses were made of 26 samples besides the composite, which was a mixture prepared by carefully igniting in a muffle two grams of the ash of each of the 187 samples of cactus analyzed.

TABLE I.—*Chemical analyses of representative samples of cacti.*

Number of sample.	Scientific name of cactus.	Locality.	Date of collection.	Formula.[a]	Total ash in air-dry plant.	Carbon.	Sand.
					P. ct.	*P. ct.*	*P. ct.*
6255	Opuntia fulgida	Santa Catalina Mountains, Ariz.	May 4, 1904	(6-6)	14.25	.74	1.65
6331	Echinocereus enneacanthus	Eagle Pass, Tex.	May 10, 1904	Plant	17.78	.26	3.31
3000	Opuntia macrocentra	Garfield, N. Mex.	July 11, 1904	....	16.45	.62	4.27
6699	Cereus giganteus	Tucson, Ariz.	July 28, 1904	....	15.75	.17	.44
7515	Opuntia lindheimeri	Encinal, Tex.	Jan. 17, 1905	(2-1-1)3	21.05	.14	.29
	Composite				....	.38	3.17
	Average of all ashes				19.65	.40	2.40

Number of sample.	Scientific name of cactus.	Pure ash.												
		Iron (Fe).	Aluminum (Al).	Manganese (Mn).	Calcium (Ca).	Magnesium (Mg).	Potassium (K).	Sodium (Na).	Silicic acid radical (SiO_3).	Phosphoric acid radical (PO_4).	Sulphuric acid radical (SO_4).	Chlorin (Cl).	Carbonic acid radical (CO_3).	Total.
		P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
6255	Opuntia fulgida	0.21	0.53	0.09	24.31	8.10	11.89	0.00	0.63	2.54	2.00	1.33	42.73	94.36
6331	Echinocereus enneacanthus.	.31	.13	.09	22.66	5.07	16.61	.62	.80	1.20	2.35	2.90	42.63	95.37
3000	Opuntia macrocentra.	.53	.00	.56	24.75	8.25	8.33	1.57	1.56	2.14	1.16	.95	44.80	94.60
6699	Cereus giganteus	.30	.07	.15	31.64	5.78	6.66	.00	.37	.88	4.12	3.32	41.06	94.55
7515	Opuntia lindheimeri.	.20	.00	.49	26.71	2.27	14.22	.35	.43	1.11	1.15	2.15	49.12	98.26
	Composite	.36	.31	.83	28.90	6.85	10.49	.47	1.90	2.70	1.94	2.20	33.76	90.71
	Average of all ashes.	.31	.24	.36	27.38	5.31	9.71	.42	1.58	1.39	1.64	1.84	45.90	95.75

[a] For explanation of formula, see page 6.

FOOD VALUE OF DIFFERENT PARTS OF THE PLANT.

The opinion is prevalent in southern Texas that the old woody stems of *Opuntia lindheimeri* fed there are much more valuable as a stock food than the younger growths. So firmly do many believe this that they practice cutting off and throwing away two or three of the terminal joints when feeding. In Mexico, on the contrary, the young growth is always fed; but there the species are commonly much larger and stouter, and the trunks are altogether too woody to be fed even if it were desirable to do so. The reasons for the opinions current in Texas are rather clearly brought out in the analyses. The younger growth has a relatively higher water content, and therefore probably causes more scouring, which is the only evil influence overcome by a rejection of it. On the other hand, the old stems contain a much larger proportion of fiber and are really of less forage value.

Guthrie,[a] after comparing his own analysis of the stems of four Australian species with the analysis of fruits made by Wolf, concludes that the latter are of less forage value than the stems, because they contain a smaller proportion of nutritious substance and more crude fiber. Forbes,[b] on the other hand, concludes from analyses of Arizona cylindrical-jointed species that the fruits of these species are relished by cattle on account of their high ether extract (including fats). Our analyses show that the ether extract is mainly a constituent of the seeds, and since these pass through cattle undigested can contribute nothing to either the palatability or nutritive value of this part of the plant. That the seed is not digested is plainly shown in the case of *Opuntia lindheimeri* in many favorable seasons in portions of Texas. In the vicinity of Austin, in the early spring of 1904, there were numberless young plants springing up from cattle droppings in many of the pastures. They were fully as numerous in some situations as are the seedlings of the mesquite under similar conditions in favorable seasons in the river valleys of Arizona and on the plains of southern Texas.

This applies to the genus Opuntia, to which belong the prickly pears and cane cacti. The seeds of the other group are very different in character. There is no doubt that burros, which commonly feed upon the fruits of the viznaga (*Echinocactus wislizeni*), get a great deal of nourishment out of the seeds, which are very oily and easily masticated. It is interesting to note that No. 8170a (*Opuntia fulgida*) contains but little more food value in the whole fruit than is found in the pulpy portion alone, but in this sample most of the seeds were poorly developed or sterile. Other samples of fruit of the same species show an apparently greater food value.

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[a] Agricultural Gazette, New South Wales, 11: 671. 1900.

[b] Arizona Agricultural Experiment Station, Annual Report, 15: 496. 1904.

TABLE II.—*Chemical composition of the different parts of fruits of cacti.*

Number of sample.	Scientific name of cactus.	Part of fruit analyzed.	Water.	Ash.	Protein.	Fat.	Nitrogen, free extract.	Fiber.	Organic matter.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
8022a	Opuntia phaeacantha	Seed	7.26	1.75	6.07	11.41	23.18	50.33	90.99
8022b	Opuntia phaeacantha	Pulp	92.50	2.09	.20	.07	4.63	.51	5.41
8162a	Opuntia spinosior	Whole fruit	77.74	2.97	1.74	1.11	11.50	4.94	19.29
8162b	Opuntia spinosior	Pulp	83.04	3.10	.55	.24	11.74	1.33	13.86
8173a	Echinocactus wislizeni.	Seed	8.59	3.09	10.92	15.46	36.59	25.37	88.31
8173b	Echinocactus wislizeni.	Pulp	94.14	.96	.63	.06	3.05	1.16	4.90
8170a	Opuntia fulgida	Whole fruit	82.84	2.70	.63	.51	11.63	1.69	14.46
8170b	Opuntia fulgida	Pulp	87.17	1.58	.47	.27	9.66	.91	11.25

It must be undertood that we have analyzed here but few fruits aside from those which are of more value for forage than they are as food for man. None of the cylindrical-jointed species and but few of the native prickly pears of the United States bear edible fruits.

A BALANCED RATION OF PRICKLY PEAR.

To determine in just what proportion cactus should be fed with other foods to produce a balanced ration, it is necessary to know the amount of digestible nutrients contained in the cactus, as well as those of the food or foods with which it is to be fed. This has been determined for most foods, but unfortunately there are as yet no such data for the cacti. It is hoped to be able soon to obtain the coefficient of digestion for *Opuntia lindheimeri.* For the present, all that can be done is to assume this digestibility coefficient to be the same as that of some food as similar in chemical composition and properties to the cacti as possible. It is somewhat difficult to secure a green fodder very similar in character to cactus, but perhaps its digestion coefficient will not be missed very far by assuming it to be the same as that of immature green corn fodder. By using the coefficient for this fodder the nutrients in *Opuntia lindheimeri* are found to be: Protein, 0.47 per cent; fat, 0.26 per cent; carbohydrates, 7.85 per cent. This being the case, cactus would have a nutritive ratio of 1:18, a ratio which according to the best authorities would prohibit its use alone for any feeding standard. The nutritive ratio for a standard ration varies from 1:4 to 1:12, depending upon the age, character, and kind of animal to be fed, as well as the object of the feeding; that is, whether it is desired to produce work, flesh, or milk.

If the object of feeding is to produce milk, a cow giving a heavy yield of milk should, according to the best authorities, be fed about 25 to 30 pounds a day of organic matter, containing from 1.8 to 2 pounds of digestible protein, from 0.4 to 0.7 pound of digestible fat, and 11 to 13 pounds of digestible carbohydrates, making a nutritive atio of from about 1:5.5 to 1:7. If a cow requiring a ration of this ind should eat cactus alone, it would take 160 pounds to furnish the ats and carbohydrates and an additional 240 pounds to furnish ufficient protein, and since to avoid scouring a cow should probbly not be fed to exceed 50 or 60 pounds of cactus a day, it may be eadily seen how impossible it would be for a milk cow to get even a ne-sided ration from cactus alone.

A ration of 40 pounds of cactus with 10 pounds of wheat bran and 2 pounds of corn stover would furnish the nutrients in somewhat ear the proper proportion. In a ration of this kind the cow would et 21.16 pounds of organic matter, containing 1.68 pounds of proein, 11.82 pounds of carbohydrates, and 0.49 pound of fat, which is n a ratio of 1:7.7.

If a ration is desired in which the cactus is fed with dried brewers' rain and cotton-seed meal, it could be made by feeding 60 pounds of actus with 14 pounds of brewers' grain and 1 pound of cotton-seed eal. In this case 20.58 pounds of organic matter are fed, containing .85 pounds of protein, 10.38 pounds of carbohydrates, and 1 pound of at. This ration would contain the nutrients in the ratio of 1:4.5. If his ration is considered too narrow, it could be widened to good advanage by feeding with it a small quantity of coarse, dry fodder, rather han by increasing the amount of cactus.

A balanced ration of cotton-seed meal and cactus can not be preared, for if the meal be fed in just sufficient quantity to furnish the roteids it would necessitate the feeding of too much cactus to suply the remainder of the carbohydrates. From this it must not be nferred that a mixture of these foods would not make a desirable ation; in fact, current successful practice has demonstrated that it ill. For example, a ration of prickly pear and cotton-seed meal was ed to steers for one hundred and five days in a recent experiment onducted by the Bureau of Plant Industry at Encinal, Tex., with a ain of 1¾ pounds of flesh a day at a cost of only 3½ cents. Any ation of these two foods that would secure this gain each day would ontain an excess of the proteids over an amount necessary for a balnced ration. Fortunately, however, an excess of proteids can be tilized in serving the function of the carbohydrates in the animal ody, and this no doubt is what took place in the above experiment. sually proteids are the most expensive foods for man and beast, nd it is poor economy to substitute them for carbohydrates; yet uch a condition is not uncommon in Texas cattle feeding, where otton-seed meal is cheaper than other more starchy foods.

RELATIVE VALUE OF THE THREE GROUPS OF CACTI.

On account of several practical considerations the prickly pea are of much more value than either of the other two groups. The are more numerous in the wild state, they adapt themselves to cultivation more readil propagated from cuttings, all of which are of vital importance in th economic use and handling of the crop. Practically all of the Mexican prickly pears are fed to stock to a greater or less extent, especially those growing where fodder is the most scarce, but there is onl one cylindrical-jointed species (*Opuntia imbricata*) which is used t any appreciable extent. The experience of the writers has shown tha *Cereus giganteus* is readily eaten by cattle when chopped up, bu they know of no actual feeding having been conducted with it o any commercial scale. Mr. C. R. Orcutt states that *Echinocactu orcuttii*, which is typical of a considerable group of species, is occasionally fed in Lower California. It is only in rare instances, however, that any great quantity of feed can be secured from cacti, outside of the genus Opuntia, and the greater part of the feed in this genus is produced by the flat-jointed forms. There are about five species in the cylindrical-jointed group which have been fed with some success. *Opuntia imbricata*, from Mexico, has been referred to, and in various writings the use of *Opuntia arborescens*, *Opuntia spinosior*, and *Opuntia fulgida* are mentioned. To these should be added *Opuntia prolifera* from the coastal region of southern California. These species constitute, without doubt, the best of the cylindrical-jointed group, and when extent of territory covered, succulence, and ease of propagation are taken into consideration *Opunti fulgida* and *Opuntia imbricata* are probably the most valuable o this group. *Opuntia arborescens* has a decidedly valuable characteristic in that it extends farther to the north than any of the othe economic species of any of the groups, and it is fed to a considerabl extent in localities from southern Colorado southward.

The use of these species, however, and, in fact, the extended use o nearly all the native species of this country and Mexico, presuppose artificial preparation. In dry seasons in southern Arizona, cattle feed upon the pendent bunches of fruits of the cholla (*Opuntia fulgida*), but it is done at a great sacrifice of comfort. The Texas pea (*Opuntia lindheimeri*) is grazed to a considerable extent by cattle sheep, and goats without any preparation whatever, and even suc thorny forms as cardon, shown in Plate I, are grazed by cattle i extreme cases.[a]

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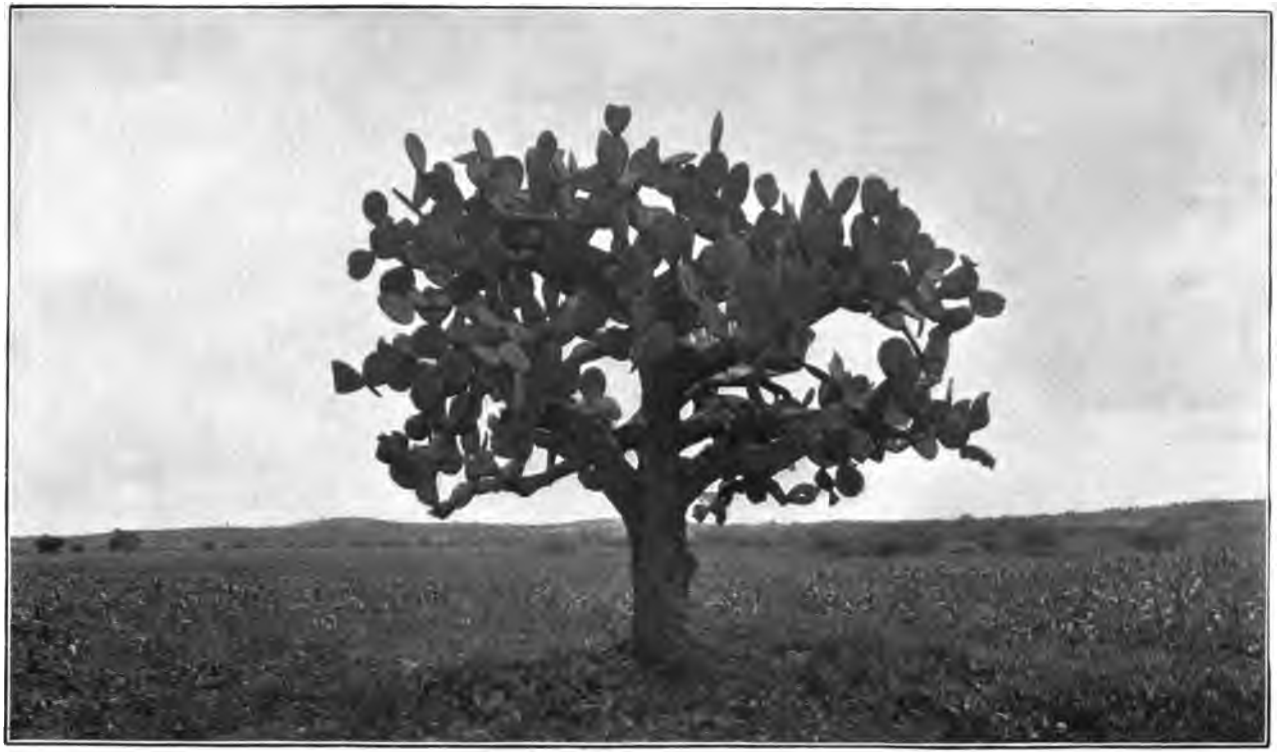
[a] For further discussion, see Bulletin 74 of the Bureau of Plant Industry.



NOPAL CARDON (OPUNTIA STREPTACANTHA LEHM.), THE MOST IMPORTANT OF THE MEXICAN PRICKLY PEARS.

COMMON AND SCIENTIFIC NAMES.

Considerable attention has been given to the popular names by which the various species are designated, especially the larger Mexican forms, but inasmuch as these are to be more fully considered in another publication now in process of preparation a full discussion of the subject is postponed.

The chaotic condition of the scientific literature and the general imperfection of knowledge of prickly-pear forms have rendered it very difficult to properly name the species discussed. The purpose of the writers has been to present the exact status of their information, indicating a doubt wherever one occurs. The Engelmann species, which are largely United States forms, are comparatively easily determined, in most cases through a reference to the types in the herbarium of the Missouri Botanical Garden. In case of long-established species, however, it is absolutely impossible to correlate the specimens with the literature and determine what name belongs to the plant under discussion. *Opuntia tuna*, for instance, has been paraded in literature a great deal, and to it has been assigned all sorts of species; but, as pointed out by Berger and Maiden especially, no one knows what the species is, and the writers know of no way by which its identity can ever be determined.

Some species are referred to their proper genera only. Others are given common names besides, but the majority of them are given scientific names. All species receiving chemical analyses are represented in our collections by specimens mounted upon sheets in the ordinary way or put up in boxes or in liquid. Many are growing in conservatories or upon one of the plantations maintained by the United States Department of Agriculture, while the seeds of many species have been widely distributed to those interested in the scientific and economic study of the group. The work is therefore well supported by specimens to which access will be had in completing in the future such naming as has not hitherto been undertaken. It was early recognized that good dry specimens were absolutely necessary for this work in order to make the chemical analyses and determinations of permanent value.

Whenever a sample or set of samples represents a striking or constant variation it is treated separately in the text; consequently *Opuntia lindheimeri*, for instance, appears several times under two or more headings. Each number or group of numbers is accompanied by a brief set of notes made in the field beside the plant when the samples were collected, elaborated and perfected by subsequent experience. These are presented as field notes simply and not as full technical descriptions. This rather full set of notes, popular and scientific names, and, as a final resort, our specimens and photographs, will make it possible to easily verify the determinations of the writers.

CLIMATIC REQUIREMENTS OF PRICKLY PEARS.

Prickly pears and other cacti are apparently inseparably connected in the public mind with drought and heat, but this conception of the requirements for their best development is far from perfect. Our driest deserts produce none of these plants in economic quantities, and the same is true of our hottest regions. Rather than say they are adapted to conditions of extreme heat and drought, it should be said that they thrive best in a region which has an equable temperature and a considerable rainfall periodically distributed. There is certainly no region in the world where these plants grow naturally in such profusion as they do upon the plateau of Mexico, but this is not a hot country; neither is it excessively dry. It is very dry during a large part of the year. It is a desert as compared with eastern Texas, for instance, but it has a considerable rainfall during an average year. The rain falls mostly in the summer, and then the country looks like anything but a desert. The average rainfall at Zacatecas for the past ten years, as stated by Mr. Albert L. de Lautreppe, who has made a special study of the weather records of that city in connection with a business venture, is 31½ inches, but the average for the seasons from January to April and from October to December is only five-eighths of an inch to 2⅛ inches, while the average for the other months of the year is 3½ to 7⅛ inches a month. June, July, and August are the rainy months, having an average rainfall of 4¼ to 7⅛ inches each for the past ten years.

While many species appear to be able to withstand high temperatures, they develop naturally in the greatest profusion where the heat is not excessive. The plateau of Mexico is a region with comparatively equable climate. Some species thrive under extremes of heat. *Opuntia lindheimeri* is at home in the lower Rio Grande Valley of Texas and Chihuahua, and the closely related *Opuntia engelmanni* and *Opuntia engelmanni cycloides* thrive in southern Arizona, where the mercury often reaches 111° F. On the other hand, there are species which grow where the winter temperatures go to at least –40° F., but the plants are small and of no economic importance in themselves except as they may be used to give a hardy character to more valuable species. The valuable species of the Mexican highlands thrive where the temperature falls to 14° F. in very rare instances. Usually the freezing point is only rarely reached here. During the past winter (1905–6) the mercury dropped at the city of Zacatecas to 14° F., and many of the more delicate spineless forms, as well as the natives, were badly injured. No pear was killed outright, but the branches were frozen down for four or more joints. These rotted and dropped off, but the old trunks survived. *Opuntia lindheimeri*, the common species of southern Texas, has been injured very severely within the memory of the present generation. It suffered some injury during the winter of 1904–5. In the vicinity of San Antonio many of the plants drooped badly after the coldest weather, which registered a temperature of 12° F. The majority of the plants straightened up again, but in many the distal joints dropped off as the result of freezing.

THE USE OF PRICKLY PEAR IN MEXICO.

In Mexico the use of the prickly pear is much more varied than in this country. There the established plantations are guarded from animal depredations either by rude fences or hedges of some of the tall columnar species of Cereus or the more spiny opuntias. The latter are planted thickly in borders around the more nearly spineless forms, which stock eat readily.

All of the species are fed to stock indiscriminately. Whatever is available and can be spared is singed and fed to cattle. So far as observed, the durasnillo (*Opuntia leucotricha*) is preferred to all others. This is due to some extent to its small fiber content, but more especially to its abundant delicate spines, which are singed off more readily than those of other species which have fewer spines.

However, the extent of cattle feeding upon this kind of food is not so great in Mexico as one would suppose from the abundance of the material and the great extent of time during which the practice has been in vogue. The fact is that the average Mexican peon can not afford to feed to stock what he himself can use so profitably in other ways. The prickly pear is to him primarily an article of human food, and its place can not be taken by any other plant.

The young joints as well are eaten by man in Mexico, and the dried stems and joints are used for fuel. Of course, this fuel is exceedingly poor, but it serves the purpose in that land where this commodity is exceedingly scarce. The feeding of cacti to stock, therefore, is a secondary consideration. The limbs which break off and such other portions of the orchard material as can be spared without seriously jeopardizing the tuna crop, together with such wild forms as are available, are fed to cattle. On some of the large haciendas, especially those devoted to maguey culture, the feeding of pear to work oxen during the grassless season is a regular practice, but then only wild forms are used. Over a large part of the Republic, therefore, although the prickly pears are much used for forage, their principal use is as an article of human food.

THE SPECIES OF CACTI AND THEIR ANALYSES.

In all, 67 species and varieties of cacti are discussed, all of which have been analyzed chemically, some represented by as high as five samples. One hundred and eighty-seven fodder analyses and 26 complete ash analyses have been made. The following brief table will illustrate the characteristic composition of representative samples, together with an average of all the samples.

TABLE III.—*Chemical composition of representative samples of cactus plants and fruits.*

Number of sample.	Common name of cactus.	Scientific name of cactus.	Character of sample analyzed.	Formula.	Green.								Air dry.							
					Spines.	Water.	Ash.	Crude protein.	Crude fat.	Nitrogen-free extract.	Crude fiber.	Organic matter.	Spines.	Water.	Ash.	Crude protein.	Crude fat.	Nitrogen-free extract.	Crude fiber.	Organic matter.
					P.ct.	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*	*P.ct.*
6329	Nopal, prickly pear.	Opuntia lindheimeri.	Last year's growth mostly.	(5–0–0–0)4	0.76	80.72	4.44	1.38	0.42	10.87	2.17	14.84	3.73	5.33	21.78	6.79	2.08	53.37	10.65	72.89
7571	do	do	Terminal joints	(4–0–0–0)3	Few.	88.64	1.64	.55	.29	7.72	1.16	9.72	Few.	7.03	13.40	4.49	2.40	63.15	9.53	79.57
6330	do	do	From old stems		.58	77.95	5.81	.92	.41	11.58	3.33	16.24	2.51	5.14	25.00	3.94	1.78	49.81	14.33	69.86
7572	do	do	do	(0–0–0–0–1–1–1)3.	Few.	84.49	2.42	.36	.27	8.80	3.65	13.08	Few.	6.35	14.60	2.19	1.65	53.18	22.03	79.05
6542	do	do	Early-maturing fruits.		Few.	92.19	1.09	.65	.49	2.85	2.73	6.72	Few.	4.85	13.23	7.88	5.95	34.89	33.20	81.92
6530	Nopal tapon	Opuntia robusta.	Joints 1–3 years old.	(2–2–1)5	.71	89.62	2.95	.63	.23	4.81	1.76	7.43	6.43	5.68	26.81	5.70	2.13	43.70	15.98	67.51
7590	do	do	Joints 1–5 years old.	(1–0–1–0–1)3	.25	89.62	1.93	.46	.18	5.98	1.83	8.45	2.33	4.55	17.79	4.27	1.64	54.95	16.80	77.66
6529	do	do	Partly mature fruit.		Few.	88.59	1.29	1.06	1.13	3.84	4.09	10.12	Few.	5.41	10.70	8.76	9.38	31.80	33.95	83.89
6531	do	do	Mature fruit		Few.	96.81	.26	.23	.23	1.80	.67	2.93	Few.	6.38	7.65	6.79	6.76	52.72	19.70	85.97
6254	Cholla	Opuntia fulgida.	Joints 3–4 years old.	(0–0–6–1)	1.78	72.63	3.88	.95	.43	20.39	1.72	23.49	6.13	5.60	13.40	3.29	1.48	70.27	5.96	81.00
6255	do	do	Joints 1–2 years old.	(6–6)	2.27	78.03	3.36	1.30	.35	15.37	1.59	18.61	9.60	6.95	14.25	5.48	1.48	65.09	6.75	78.80
7802	do	do	Joints 4–6 years old.	(2–3–2)7	1.72	81.51	2.21	.96	.28	14.21	.83	16.28	8.64	7.10	11.10	4.82	1.41	71.41	4.16	81.80
7796	do	do	do	(0–0–0–1–2–1)3	.94	70.33	2.73	.95	.43	17.99	7.56	26.94	2.96	6.19	8.63	3.00	1.36	56.92	23.90	85.18
6253	do	do	Fruit		Few.	83.48	2.79	.59	.36	11.18	1.60	13.73	Few.	4.88	16.05	3.39	2.09	64.36	9.23	79.07
7801	do	do	Fruit 1–6 years old		Few.	80.29	3.25	.56	.47	13.77	1.66	16.46	Few.	5.43	15.60	2.70	2.24	66.05	7.98	78.97
8170a	do	do	Fruit, largely sterile		Few.	82.84	2.70	.63	.51	11.63	1.69	14.46	Few.	5.16	14.99	3.50	2.85	64.12	9.38	79.85
8170b	do	do	Fruit, largely without seed		Few.	87.17	1.58	.47	.27	9.60	.91	11.25	Few.	4.55	11.73	3.50	1.98	71.49	6.75	83.72
6561	Sewarah	Cereus giganteus	Mature fruit		Few.	91.62	.98	1.05	.61	3.64	2.10	7.40	Few.	5.88	11.05	11.83	6.86	40.73	23.65	83.07
6699	do	do	4 sections of stem		.92	87.31	2.20	.81	.17	8.07	1.44	10.49	6.63	8.98	15.75	5.80	1.20	57.92	10.35	75.27
7805	do	do	3 sections of stem		.28	92.36	1.30	.67	.16	4.45	1.06	6.34	3.41	5.80	15.98	8.28	1.94	54.95	13.05	78.22
	Average of all prickly pears analyzed				.44	84.26	3.06	.73	.34	9.04	2.41	12.53	2.53	5.89	18.25	4.61	2.24	54.26	14.77	75.86
	Average of all cane cacti analyzed				.79	78.47	3.61	1.41	.63	12.30	3.59	17.93	3.32	6.15	15.50	6.09	2.77	54.32	15.17	78.35
	Average of all miscellaneous group analyzed				1.03	87.88	1.67	1.05	.41	7.22	1.76	10.45	8.62	6.53	13.54	8.49	2.84	54.96	13.63	79.93

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A SUCCESSFUL DAIRY FARM.[a]

By L. G. Dodge, *Scientific Assistant, Farm Management Investigations.*

INTRODUCTION.

In Delaware County, N. Y., is a farm of 200 acres, owned by John T. McDonald and managed by him as a dairy farm. About half of the land is meadow and half is permanent pasture. A small portion of the meadow is each year plowed up for other crops—a few acres of corn for soiling and a few acres of peas and oats for hay. This farm lies in the valley of a tributary of the Delaware River and extends up the hills on either side, so that the tillage land is gently rolling, while the pasture is comparatively steep. The soil is a reddish brown loam, originally filled with fragments of shale rock. The dwelling house, barn, and dairy are located on the highway at a little distance from the creek, and the mill and tenant houses near the road crossing the creek. (Pl. I, fig. 1.) The water supply is abundant, coming from several springs nearly 100 feet higher than the buildings. The shipping point is 5½ miles distant, over an easy road.

The dwelling house of the owner is provided with good plumbing, is well heated, and is lighted by electricity. The barn contains 124 cow stalls on the main floor and has a manure cellar below. The second floor can be driven upon also, and has six horse stalls and a grain room, while most of the remainder is used as a hay loft. The dairy building adjoins the barn and is equipped with steam power and the necessary machinery for butter making. A small mill for sawing and planing and for grinding grain is run by water power from the brook. In this building is a small dynamo, also run by water power, which furnishes light for all the buildings, including the cow and horse stables, the dairy building, and the three small houses for the farm hands, as well as the owner's residence. There are also a small tool shed and hay barn near the large barn and a tool shed near the mill.

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[a] This article is one of a series issued by the Bureau of Plant Industry giving the results of the study of systems of management on successful farms of various types. The cropping system on the farm here described is unique, in that half the land is in permanent pasture and half in nearly permanent meadow. Each year a few acres of the meadow that seem most to need resetting are broken up, sown to peas and oats with which grasses and clovers are seeded, or planted to corn for soiling, this to be followed by peas and oats with grasses and clovers. The special lesson to be learned from this farmer's practice is the method of managing permanent grass land to maintain its productivity.—W. J. Spillman, *Agriculturist in Charge of Farm Management Investigations.*

The farm supports about 100 head of milch cows, 25 head of young stock, 600 hens, 5 horses, and 3 or 4 hogs. Eight hired men are employed the year round. More cows are in milk in winter than in summer and the extra work in the dairy compensates for the decreased field work in winter.

The equipment of implements, tools, machinery, etc., is as follows: Two plows of the swivel type (hillside plows); 2 harrows; 1 manure spreader; 1 grain drill; 1 6-foot mower; 2 hay rakes (1 one-horse, 1 two-horse); 1 tedder (one or two horse); 2 wagons, with hay racks and brake; 1 express wagon; 1 set of ice tools; dairy equipment; saw and grist mill equipment; dynamo and lights; 1 incubator.

The land is not divided by fences into small lots, but is inclosed entirely by a stone wall, which was built when clearing the land of stone, for all the land was formerly as stony as the pastures now are. (See Pl. I, fig. 2.) Some of the tillage land has been drained with stone underdrains, and from a good deal of it there has been a great number of old pine stumps pulled out.

THE ROTATION FOLLOWED.

The rotation on this farm, if such it may be called, is exceedingly simple. Broadly speaking, half the land is in permanent pasture and half in meadow. Most of the 100 acres of meadow land is in grass and clover. Each year about 12 to 15 acres of this grass that seem most to need renewing are broken up. Of this, 2 or 3 acres are devoted to corn for green feed in late summer, to be followed by peas and oats the next spring. The remaining 10 to 12 acres are sown at once to peas and oats for hay. In each of these cases grass and clover are sown with the peas and oats, the land thus being returned to semi-permanent meadow. If the seeding fails, it is repeated after the peas and oats are cut for hay. This gives a long period during which the land stays in grass, but owing to the fact that the owner spreads the manure from more than a hundred head of live stock upon this land, hauling it at nearly all seasons of the year, midwinter and haying time excepted, the fields are kept in such a productive condition as to cut an average of 2 tons of hay per acre over the entire meadow area, including the peas and oats.

As soon as the ground is hard enough to drive over in the spring, the manure is brushed with a brush harrow, the man who drives the harrow sowing at the same time a very light application of clover seed—so light, in fact, that 1 bushel of red clover and 1 bushel of alsike mixed go over the greater part of the 100 acres. Or, when manure is being spread in the spring, some clover seed is applied by sprinkling about a cupful on top of the loaded manure spreader. This plan

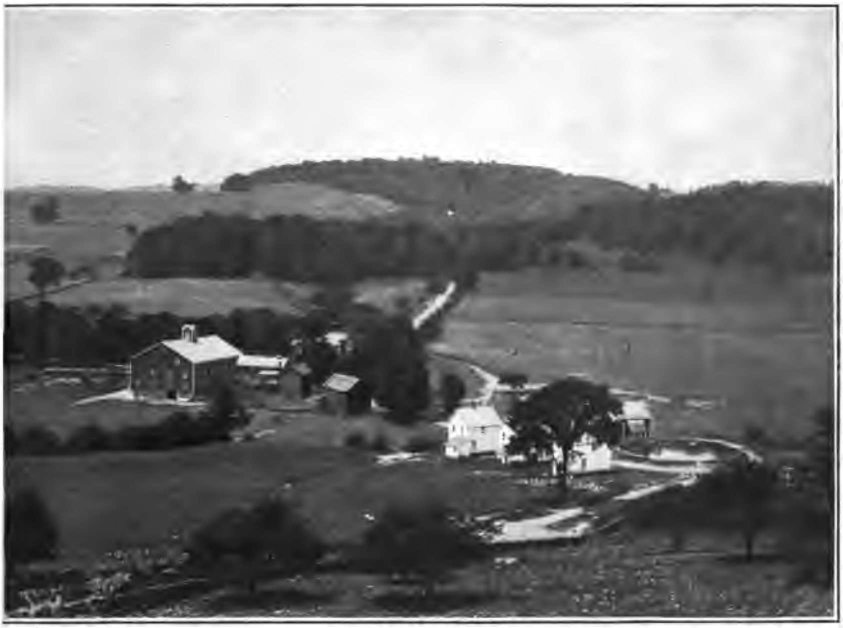

FIG. 1.—VIEW ACROSS THE LOWER END OF THE McDONALD FARM, SHOWING THE BUILDINGS, THE DWELLING HOUSE BEING PARTIALLY CONCEALED IN THE TREES.

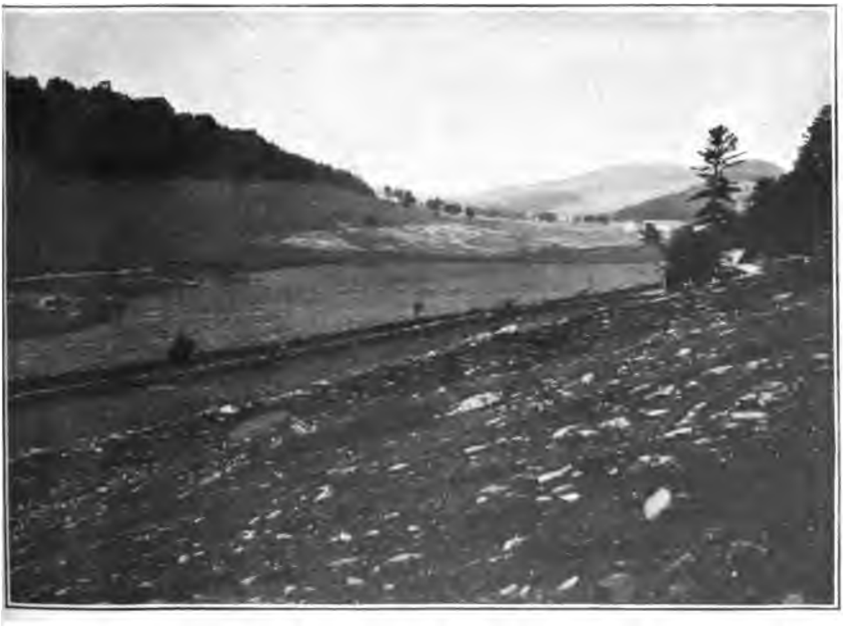

FIG. 2.—VIEW ACROSS THE UPPER END OF THE FARM, SHOWING THE STONY NATURE OF THE LAND IN THE PASTURE, THE PRESENT CONDITION OF THE HAY LAND, AND THE LOCATION OF THE MILL POND.

provides for renewal of the clover and, through the agency of the clover and manure, maintains a better condition of the other grasses. The owner believes also that the seedling plants of the clover hold better through an unfavorable winter in the sod than they would in a newly fitted seed bed. The manure is applied, so far as possible, with a spreader.

Oats and peas are seeded at the rate of 2 bushels of oats and 1 of peas per acre; with these 6 quarts each of timothy and clover per acre are sown, the drill with which the grain is sown being provided with a grass-seed attachment. Then if the oats lodge or the season is unfavorable, so that the grass is killed out, a new application of seed is made as soon as the oats and peas are cut, and the seed worked in with a brush harrow. Following this a light coating of manure is put on with the spreader. If the field should come in full of weeds it would be replowed before seeding, but in any case the owner's plan is to get a stand of grass as soon as possible, that being his best crop.

HARVESTING THE HAY.

Since hay is the principal crop on this farm, it is worth while to consider the method employed in putting in the hay and the utilization of labor at that work. On the first day of hay harvest one man runs the mower in the forenoon; another man runs the tedder in the forenoon and the rake in the afternoon. Late in the afternoon one or more men begin cocking the raked hay.

In the forenoon of the second and later days one man with a team runs the mower, another the tedder, and four men spread out the hay cocked the previous afternoon in order that it may dry. In the afternoons two men and teams haul hay from the field to the barn. The proprietor works the hay fork on the loaded wagon, two men distribute the hay in the mow, two pitch hay in the field, one rakes the hay cut and tedded in the forenoon, and another cocks the raked hay. The man last mentioned also finds time to feed the hens in the afternoon.

One of the hands spends his whole time in the dairy. Another man is engaged in the dairy in the forenoons for a local dairy company whose milk is handled in Mr. McDonald's building, while in the afternoons this man works for Mr. McDonald in the hayfields or wherever needed. Consequently in the forenoons there are eight men besides the proprietor at work, and in the afternoons nine men are working on the farm.

During forenoons in hay harvest the proprietor spends his time grinding sickles and in superintending the work of his men so as to keep them all profitably employed.

From 5 to 6 o'clock in the afternoon most of the men are kept busy milking. Those who handle the work teams, however, have their teams to care for. and, during hay harvest, one of these is back in the field shortly after 5.30 and both wagons are loaded and drawn in before 6.15 o'clock. The lighter team is hitched to the two-horse rake at 6 o'clock and rakes until 7.30. The men who milk, after getting their supper go to the field for a short time to bunch up hay or load the two wagons. This makes a long day for the men, but this extra labor is required for only a short time in the busy part of the haying season: at other seasons the normal day's work ends at 6 o'clock.

Two days in the week the butter and eggs must be delivered to the station, so instead of both teams going into the field on these days one man with the lighter team starts about 7.30 o'clock a. m. for town, returning before noon. On the day that the writer watched operations closely the other team began drawing hay shortly after 8 o'clock and had in two loads by 10.30. Of twelve loads brought in during the writer's visit, two were weighed. One had 2,400 pounds of hay on it, the other 2,900. It is reasonably certain that the average was at least 2,500 pounds and all were taken off an area of not more than 5 acres, most of which had not been plowed for fifteen years. This shows a yield of approximately 3 tons to the acre and was made up wholly of fine grasses with clover mixed in, a most excellent quality of dairy feed. The teams which do this work are of good size. One pair of mares weighs 2,700 pounds, the other pair, horses, 2,860 pounds. The single rake was drawn during the afternoon by the driving horse, considerably lighter in weight.

As soon after haying as there is sufficient aftermath to furnish feed the cows are turned into the meadows, for the permanent pasture is then getting dry. Any newly seeded piece, however, is previously given a light coat of manure, which prevents the cows from grazing it down, and any other piece which would be hurt by grazing is treated likewise. The cornfield is shut off with a temporary wire fence. Some manure is spread occasionally even on the permanent pasture.

FEED FOR THE COWS AND CALVES.

As soon as the pasture gets dry and insufficient in the summer, and before the mowing land can be used, a suitable quantity of hay is fed to the cows every day, and later on the corn is fed out green. The roughage for winter feed is entirely of this mixed hay, which contains a large proportion of clover. The cows get, when in full milk, 8 pounds of grain a day, in two feeds. The grain is mixed, consisting of 1 part cotton seed meal, 2 parts ground corn, 2 parts ground oats, and 4 parts wheat bran. Skim milk is fed to the calves until they are more than a year old, and the surplus at all times is given to the milch cows.

BUTTER PRODUCTION.

The cows freshen during the fall, so that most of the butter is produced in the winter; fresh pasture comes on at such a time in the period of lactation as to prolong the flow of milk in the spring. The cows produce on an average a pound of butter each per day for three hundred days in the year—that is, 30,000 pounds of butter from 100 cows in the course of a year. The butter is sold as soon as made the year round to regular customers, mainly in New York City. The selling price is 35 cents, Mr. McDonald paying the express charges to the city. By the use of plenty of hay and skim milk for the calves as they grow up they are kept in vigorous shape and breed rather earlier than the average, so that many of the heifers are in milk at two years of age.

POULTRY PRODUCTION.

Four hundred of the 600 hens kept on the farm are housed in one long, cheaply constructed house. This house is divided so that approximately 50 hens are in each inclosure. The other 200 hens for breeding stock are kept in smaller pens in a separate location.

RESULTS ACHIEVED.

The gross receipts for a year for butter, eggs, and poultry, with occasionally a small quantity of hay sold, amount to $10,000 in round numbers. The annual expenses for grain are approximately $3,000; for labor, another $3,000. The debt on this farm in 1875 is said to have been $8,400, and to have been entirely cleared up in the twelve years following that date. The hay land has been cleared of stumps and stones, the buildings improved and added to (the dwelling house, barn, and dairy now having slate roofs), the mill and electric-light equipment have been put in, and the land rendered vastly more productive than it was in 1875.

The orchard back of the house has been made more productive by general care, and especially by burying on the up-hill side of an apple tree any animal which died on the farm.

In spite of the simplicity of its cropping system, this farm has been rendered so productive as to provide many of the comforts and conveniences usually attributed to city life, and to maintain a large family at the same time.

B. P. I.—245.

PLANNING A CROPPING SYSTEM.

By W. J. SPILLMAN, *Agriculturist in Charge of Farm Management Investigations.*

INTRODUCTION.

One of the lines of work undertaken by the Office of Farm Management Investigations is the making of working plans for farms. Some of these plans are more or less general in character, representing systems adapted to particular types of farms in definite soil and climatic areas. Others are made for individual farms.

There are two principal reasons why work of this kind is undertaken. In the first place, very few farms have any definite cropping system, and it is comparatively easy to plan a system that will meet the requirements of the case and increase the farmer's income. We are thus able to render material service to a considerable number of farmers, whose farms in consequence become centers of local interest and serve as object lessons to the community. In the second place, the number of farms on which the full possibilities of a given type of farming are realized is exceedingly small; so small, in fact, that it is necessary to increase the number very materially before many important problems relating to farm management can be solved.

To illustrate: On the farm of Mr. W. H. Rowe, described in Farmers' Bulletin No. 272,[a] the possibilities of a given system of managing swine with a particular cropping system have been worked out. One litter of pigs a year is produced. These are pastured on clover in summer and fed sufficient grain to bring them to a weight of from 100 to 125 pounds by the end of the pasture season. In winter they are fed grain and soy bean hay. The next summer they return to the clover pasture, while the feeding of grain continues. About the 1st of August they are sold, weighing from 325 to 350 pounds each. This system utilizes the full possibilities of the clover pasture. The extra hogs during early summer consume the abundant growth of clover at that season, while the smaller number later find just about the amount of pasture they can utilize. With this system the farmer is able to sell an average of six large hogs a year for each acre in clover on the farm. This farm is in the North, where winter pasture is not available. The owner knew just what acreage of each crop to grow, and he knew approximately the quantity of grain and mill feed he would need during the year. This is the only instance thus far found in which a farm devoted to hog raising had its problems so fully worked out.

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[a] A Successful Hog and Seed-Corn Farm, 1906.

Suppose, now, a hog farm is located far enough south to make winter pasture available, and that it is desired to produce 200-pound hogs. Fall litters of pigs may be given pasture and grain during winter and early summer, the grain being so apportioned as to cause the hogs to reach the desired weight, say, by the 1st of July. Spring litters may be given pasture and grain till autumn, and then penned and forced rapidly to a weight of 200 pounds. In such a system, on a farm of a given size, what acreage of winter pasture and of summer pasture should be provided? What pasture crops should be used? How much grain should be fed? These are questions that can only be answered by experience. We are able to make estimates that will serve as approximate answers, but the experience of a considerable number of farms is necessary before these estimates can be relied on.

There are similar questions that need to be worked out in connection with nearly every type of farming for every section of the United States. One of the most important reasons why detailed plans are drawn in this office for individual farms is, therefore, to enable us to find valuable material for the study of the possibilities of the various types of farming. Among a large number of plans furnished, some will result in the development of farms to their full possibilities. Every such farm is an object lesson of great value. A large number of such farms would furnish data for generalizations of inestimable value.

The number of distinct types of farming is large, and most farms combine two or more of these types. Even farms of exactly the same type—as, for instance, dairy farms that grow only roughage and buy all the concentrates—may and do have widely different cropping systems. This is true even on contiguous farms of the same type. This field of research is therefore a wide one. It relates in a most vital way to the development of the agricultural resources of the country. If properly pursued it can not fail to result in the accumulation of a vast number of important facts and principles which can be put into pedagogical form and thus become an important subject of instruction in schools.

In attempting to plan a cropping system to fit exactly the needs of a farm, the objection may be raised that this is impossible because of the great seasonal variation in yields. This objection overlooks the fact that every farmer in the United States is actually compelled to make such plans every year, whether they are feasible or not. There can be no two answers to the question whether we shall attempt to aid the farmer in this the most important work he has to do. If agricultural science is of any value at all it must aid the farmer in planning his work. With sufficient study, the ordinary fluctuations in yields become known quantities, and allowances can be made for them. When a farm is heavily stocked, it will occasionally occur that feed will run short. In such cases the only resource is to buy, unless the farmer is willing to dispense with a portion of his stock. It should be remembered that when a farmer is buying feed he is also buying fertility. One of the most successful farmers in this country says: "I usually keep enough stock to eat all I raise, and I usually take the chance of keeping a little more; for it does the farm no harm to buy a little feed if it is needed."

FARM SELECTED TO ILLUSTRATE THE METHODS USED IN PLANNING A CROPPING SYSTEM.

The plan selected to illustrate the methods used in arranging a ropping system to fit definite conditions is one recently drawn for farm in northern Illinois. The man- ger had already determined approxi- nately the possibilities of this farm nder the particular type of farming e desired to follow. The number of onditions to be met was unusually arge. Figure 1 .shows the arrange- nent of the farm as it was presented o us. It will be seen that the arable and aggregates 103 acres. This is all ood land, sloping in a fairly uniform nanner to the south and west, suffi- iently for drainage purposes. It was lesired to keep about 25 cows, 5 to 15 ead of horses (some of these to be kept or city owners), 50 to 60 hogs, and 100 ens. It was desired that a farmstead e reserved in the northwest corner of he arable portion.

It was preferred that all the stock hould be provided with pasture. At he outset it was plain that ordinary ermanent pastures for all this stock ould occupy too much land. It was herefore decided to provide more pro- uctive temporary pastures. The con- ition of the land justified the assump- ion of the following yields: Silage, 9 ons; hay, 2 tons; soiling corn, 7 tons. t was assumed that by feeding 5 ounds of hay or 20 pounds of soil- g corn per head daily, the pasture could be made to carry 1 cow er acre.

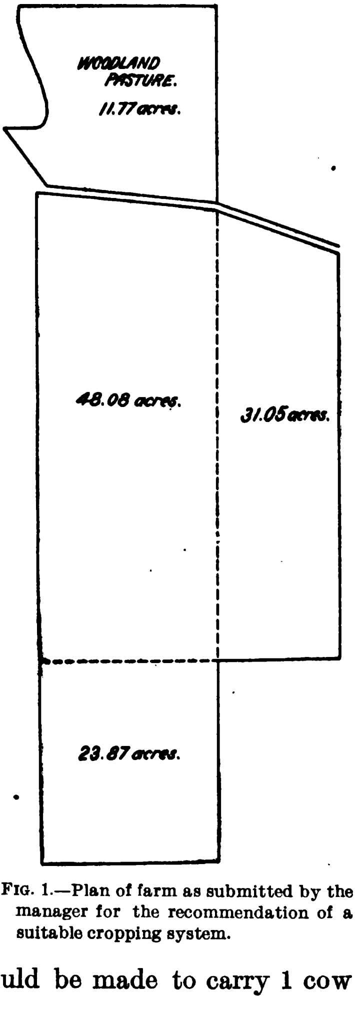

FIG. 1.—Plan of farm as submitted by the manager for the recommendation of a suitable cropping system.

In order to ascertain the quantity of feed required annually, the following system of feeding was assumed:

Cows.

May 10–October 10.—One acre of pasture per head. (This pasture will be second-year timothy and clover meadow.)

May 10–August 10.—Five pounds of hay, with pasture.

August 10–October 10.—Twenty pounds daily of soiling corn or silage with pasture.

October 10–May 10.—The average ration for dry and other cows is silage, 40 pounds; hay, 10 pounds; grain, 4 pounds.

Bulls.

May 10–August 10.—Silage, 25 pounds; hay, 15 pounds; grain, 4 pounds.

August 10–October 10.—Soiling crops, 25 pounds; hay, 15 pounds; grain, 4 pounds.

October 10–May 10.—Silage, 30 pounds; hay, 18 pounds; grain, 4 pounds.

Yearlings.

May 1–October 1.—Pasture, with 5 pounds of hay daily.

October 1–31.—Pasture, with 25 pounds of rape daily.

November 1–30.—Hay, 12 pounds, and rape, 30 pounds, daily.

December 1–April 30.—Hay, 10 pounds, and silage, 25 pounds, daily.

Calves.

First four months, an average of 15 pounds of milk, 5 pounds of hay, and 1 pound of grain daily. (This is a liberal allowance.) Five months, pasture, with 5 pounds of hay daily. One month, pasture, with 10 pounds of rape daily. Two months, hay, 9 pounds, and silage, 15 pounds, daily.

Horses.

An average of 18 pounds of hay and 6 pounds of grain daily throughout the year. This is an overestimate, since some of the horses will be at pasture part of the time, but the number of horses in winter will exceed the number in summer. Besides, it is well to have a reserve of feed in case of short crops.

Hogs.

The system of feeding hogs was assumed to be that used on the farm described in Farmers' Bulletin No. 272, already referred to. These two farms are in the same section and on soil of the same type. The Rowe system was also used, because it is the only one for which accurate data are at hand and which is adapted to the section in question.

The following table gives the number of stock and the quantity of each kind of food required, together with the yields per acre and the number of acres of each class of crops:

Number of live stock.	Silage.	Hay.	Soiling.	Grain.	Rape.	Pastur
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Acres.*	*Acres.*
25 cows	107	34	15	10.7	....	[illegible]
2 bulls	9	6	2	1.46	....	....
10 horses	....	33	....	10.95	....	[illegible]
13 young stock	15	15	....	.39	0.52	....
6 sows 48 pigs	....	2	....	35.40	....	[illegible]
Total	131	90	17	58.90	.52	[illegible]
Yield to the acre	9	2	7	....	....	....
Acres	14.6	45	2.43	....	.52	[illegible]

From the preceding table it is seen that the following acreages are required: Corn, 14.6+2.43=17.03; hay, 45; pasture, 40; and rape, 0.52; a total of 102.55 acres. The problem now is to arrange these acreages into suitable rotations.

The fact that the cows need 25 acres of pasture suggests one rotation on fields of 25 acres each. A part of one of these fields may also furnish pasture for the horses. The further fact that the hogs require 5 acres of clover pasture suggests another rotation on 5-acre fields. Since the necessary acreage is practically the whole of the arable land it will be necessary to double-crop a few acres in order to secure space for the farmstead. No estimate of pasture for young stock is included in the table. Since it is desirable to keep about half as many of these as there are mature cows, in order to maintain a high degree of efficiency in the herd, it happens that the tract of 11.77 acres of woodland pasture north of the road just about suffices for the young stock.

THE ROTATIONS ADOPTED.

A careful consideration of the conditions specified and of the many different possible rotations led to the adoption of one three-year rotation as follows: First year, 7 acres of corn and 18 acres of peas and oats; second year, timothy and clover; third year, timothy and clover.

This rotation requires that timothy and clover be sown in the 7 acres of corn at the last cultivation, a common practice in New England and a successful practice on several farms in Iowa, Missouri, and other Western States. Timothy and clover are also to be sown either with the peas and oats, or immediately after the latter are harvested for hay. The third year of this rotation furnishes the necessary pasture for the cows; the second year furnishes the required 10 acres of pasture for the horses and 15 acres for hay. This will equire a temporary fence, which, however, is entirely feasible.

In case the seeding of grass fails, rye may be sown after the corn in he fall, to be followed by soy beans for hay the next summer. If he seeding of grass after the peas and oats fails, winter wheat should be sown on the land needed for horse pasture. This will furnish good pasture throughout the summer, as the wheat will not stool until late in the fall or early the next spring. The remainder of the pea and oat land may very properly be planted to sorghum for hay. The next year the whole 25 acres may be sown in winter wheat in the pring, to be used by the cows for pasture during the summer.

To secure the 5 acres of clover for the hogs, in a rotation in which he remaining crops are useful, the following three-year rotation was rranged: First year, corn, in which clover is sown at the last cultivation; second year, clover; third year, peas and oats for hay, followed by rape sown in midsummer.

This rotation permits more rape to be grown than is strictly needed, but the extra quantity can be utilized by the pigs and calves.

If the seeding of clover in the corn fails, sow winter wheat in half of it in the autumn. Pasture this wheat down the next spring, and follow it by sorghum for hog pasture, turning the hogs in on the sorghum when it is about 18 inches high. The other half of the land should be planted to winter wheat in the spring. This will furnish good pasture for hogs throughout the summer.

These two rotations occupy 90 acres of land, and furnish 12 acres of corn, 38 acres of hay, 5 acres of rape, and all the pasture needed. There are still needed 5 acres of corn and 7 acres of hay. Reserving 3 acres for the farmstead, 10 acres on which to grow these crops are left. The evident solution of this problem lies in a two-field rotation of corn, 5 acres, followed by a double crop of hay the next year. Fortunately, the farm described in Farmers' Bulletin No. 272 has shown that soy beans are not only an excellent hay crop in that section, but that they may be planted as late as the last week in June. This fact suggests rye as a winter hay crop. Only 2 acres of this need be used for hay, since only 7 acres of hay are needed and the soy beans furnish 5 acres. The remaining 3 acres of rye will be convenient for bedding. Accordingly, the following two-year rotation was laid out for two 5-acre fields: First year, corn, followed by fall-sown rye; second year, rye followed by soy beans.

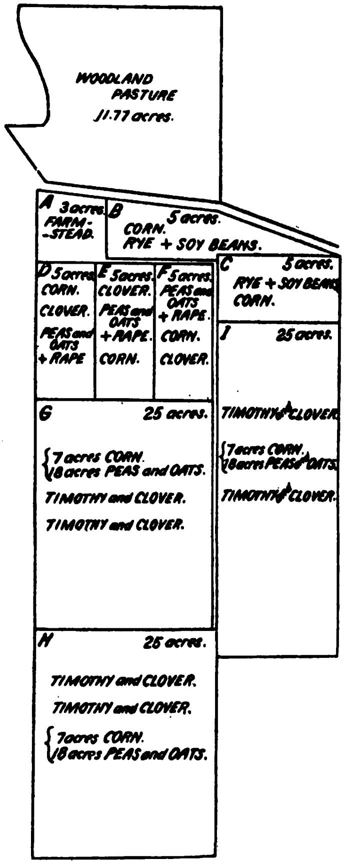

FIG. 2.—Final arrangement of the several fields, showing the cropping system recommended.

It now remains to fit these three rotations into the arable land. Figure 2 shows the final result. This arrangement permits a single road to reach every field on the farm. The peculiar outline of the farm makes this road rather long, but it would be hard to avoid this slight difficulty.

Fields G, H, and I, figure 2, are to be devoted to the three-year rotation consisting of 7 acres of corn and 18 acres of peas and oats the first year, followed by timothy and clover left down two years. The other three-year rotation on 5-acre fields may be run on any three of the fields B, C, D, E, and F, with the two-year rotation on the remaining two. The farmstead occupies the 3 acres in subdivision A. This gives room for a tenant house, barn, chicken house, and a small garden.

On receiving the above plans, the manager of this farm wrote: "I have carefully read your suggestions as to the field arrangements of the farm and the plan of operation. I do not see why I can not carry out every suggestion to the letter."

The results of the operation of this plan will be carefully studied by this office. It will be seen that some features of the plan are somewhat experimental, at least for that locality. Other features are based on successful practice on near-by farms.

ARRANGEMENT OF CROPPING SYSTEMS FOR FARMS.

It is hoped that ultimately it will be possible by the study of farm practice on the best farms to arrange rotations in all parts of the country based entirely on successful local practice. While this office can not undertake to furnish detailed plans for an indefinite number of individual farms, at the same time we desire the opportunity to do a considerable amount of this work, in order that we may test the possibilities of certain types of farming and enlarge the number of highly successful farms, so that we may have more material for the study of farm management. Ultimately it is hoped to formulate generalized plans for farms of various types in all sections of the country, and to make these plans available in our publications.

B. P. I.—246.

THE APPLICATION OF VEGETATIVE PROPAGATION TO LEGUMINOUS FORAGE PLANTS.[a]

By J. M. Westgate, *Assistant Agrostologist in Charge of Alfalfa and Clover Introduction, Forage Crop Investigations,* and George W. Oliver, *Plant Propagator, Seed and Plant Introduction Investigations.*

INTRODUCTION.

The practical difficulties which have presented themselves in connection with the development of improved strains of perennial forage plants have been such as to retard the progress of the work. The necessity for isolation to prevent promiscuous pollination and the time required to secure any considerable quantity of seed have together served to handicap seriously the work of developing new strains of forage plants, especially the perennial legumes. The method of propagating forage plants by means of cuttings herein described has been worked out chiefly in connection with *Medicago sativa* and *Trifolium pratense,* but preliminary experiments indicate that it may be quite as successfully adapted to all dicotyledonous forage plants. Among the species which have been successfully propagated in this manner may be mentioned *Medicago sativa, Melilotus officinalis, M. alba, Trifolium pratense,* and *T. repens.* By using the offsets or innovations the method is also applicable to grasses.

A number of problems in connection with the self-sterility of the different species in question demand further attention. It is hoped that the method here suggested will stimulate the work of developing varieties of forage crops throughout the country.

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[a] In the summer of 1903 a plot of Peruvian alfalfa (S. P. I. No. 9303) in the grass garden of the Department of Agriculture proved resistant to the leaf-spot disease *Pseudopeziza medicaginis*), which nearly ruined the check plot of ordinary alfalfa. Although this strain is nonhardy and ordinarily winterkills except in the southern portions of the United States, there were two plants which survived the severe winter of 1903–4 in Washington, D. C. These points, together with the hairiness, leafiness, and vigorous growth of this variety, brought it to the attention of those interested n breeding alfalfa. These plants were placed in large pots and moved to the greenhouse to be utilized in the hybridization work inaugurated by Dr. B. T. Galloway. Later on Doctor Galloway conceived the idea of raising a large number of plants of hese two individuals vegetatively, in order to produce a large quantity of seeds the ame season. This was successfully accomplished by the method here described. The adaptation of this method to the breeding of forage crops, especially the legumes, has proved so promising that it is deemed advisable to publish the results obained.—C. V. Piper, *Agrostologist in Charge of Forage Crop Investigations.*

DESCRIPTION OF THE METHOD EMPLOYED IN THE VEGETATIVE PROPAGATION OF LEGUMINOUS PLANTS.

The method, as here described, applies specifically to alfalfa. Slight modifications may be necessary in case of its application to other species.

The cuttings should be made about three inches in length, preferably from the upper portion of reasonably matured stems. Plants grown outside the greenhouse produce the best cuttings, but in case the stock plants are not near at hand it is generally advisable to transplant them to the greenhouse, cutting the stems back close to the ground. Such plants will give an abundance of good material for cuttings within two weeks. It is practicable, when the cutting material is limited in quantity, to utilize also the middle and lower portions of the stem. In any case, two or three nodes should be included in each cutting, the lower being near the base to facilitate rooting. It is possible to secure a second set of cuttings from the original ones when they have grown to twice their original height, usually about three weeks after potting. The upper cuttings of the original stem are best adapted to this second series of cuttings, as the terminal growth is not interrupted. (Pl. I, fig. 1.)

The slips should be inserted in sand (Pl. I, fig. 2) and when the largest roots are three-fourths of an inch in length they should be transferred to 2-inch pots, and later on to 3-inch pots. (Pl. II, fig. 1.) The size which the plants can attain in such pots without becoming pot-bound will permit them to be transplanted to the permanent nursery rows, if the season be suitable, or to an outside cold frame (Pl. II, fig. 2), to remain dormant till spring, in case the cuttings are made during the winter. Greenhouse facilities are desirable, though not essential. It is possible with 30 square feet of greenhouse space and 90 square feet of cold frames to secure, during a single winter, 1,000 plants from an alfalfa plant of average size. In the northern portions of the United States the conditions of the weather may be too severe to permit of transfer to outside cold frames. In the southern portion of the country cold frame protection may not be necessary, but some means should be adopted to protect the plants from other sources of danger until they can be permanently transplanted.

The efficiency of the method is shown by the fact that at least 95 per cent of alfalfa cuttings become well rooted in the pots. The newly potted cuttings should be watered sparingly and shaded from direct sunlight for the first two days. Where it has been necessary to transfer the plants to cold frames at Washington, D. C., in midwinter, the loss has been as high as 10 per cent, owing to the sudden change of temperature. Cloth protection is recommended, as the plants, having been grown in the greenhouse, are likely to be tender.

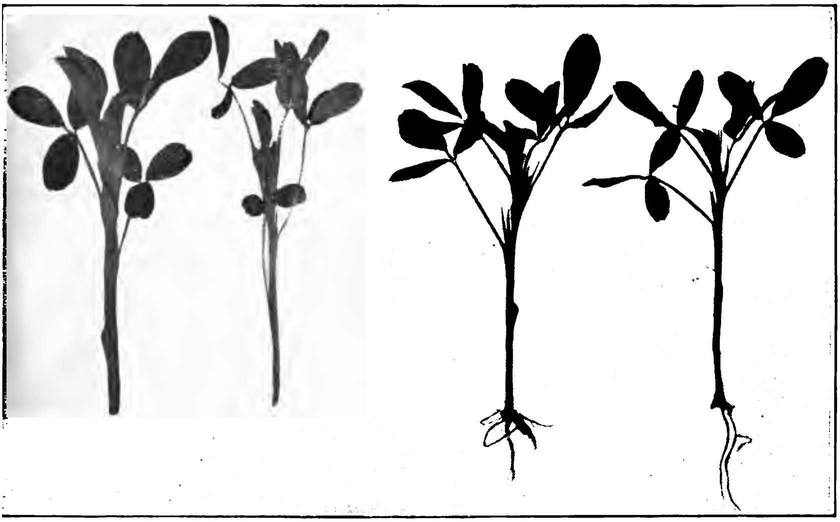

FIG. 1.—CUTTINGS OF PERUVIAN ALFALFA BEFORE AND AFTER ROOTING.

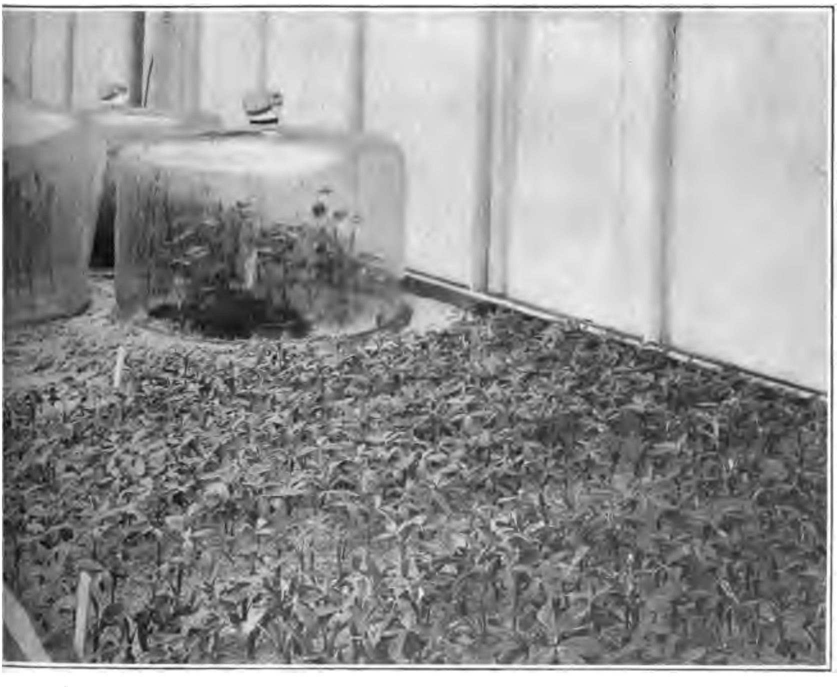

FIG. 2.—CUTTINGS OF PERUVIAN ALFALFA ROOTED IN SAND IN GREENHOUSE.

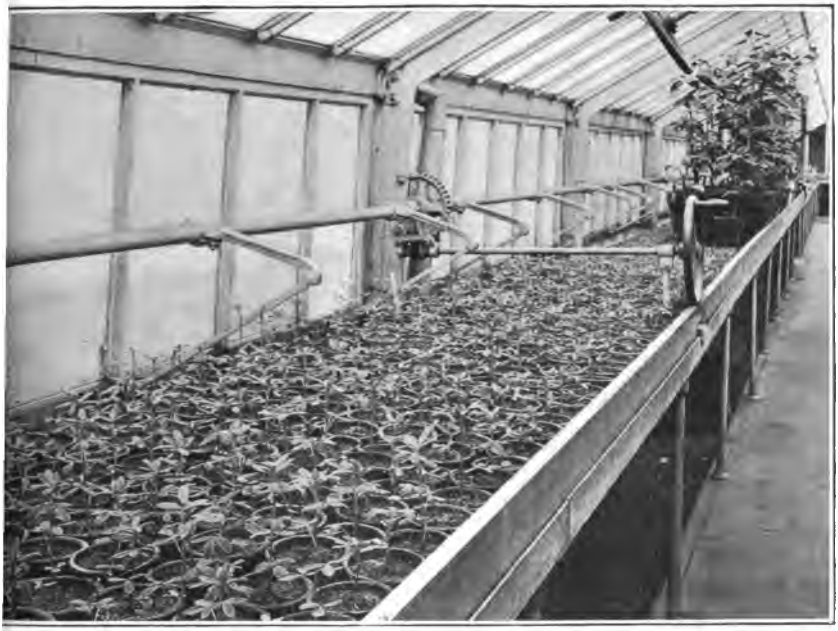

FIG. 1.—POTTED CUTTINGS OF PERUVIAN ALFALFA IN GREENHOUSE.

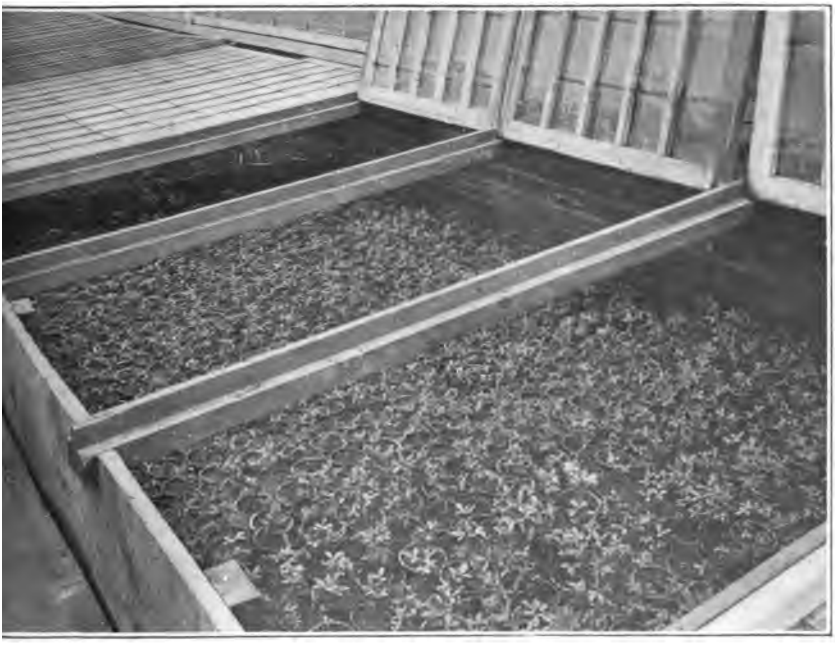

FIG. 2.—POTTED CUTTINGS OF PERUVIAN ALFALFA IN COLD FRAMES.

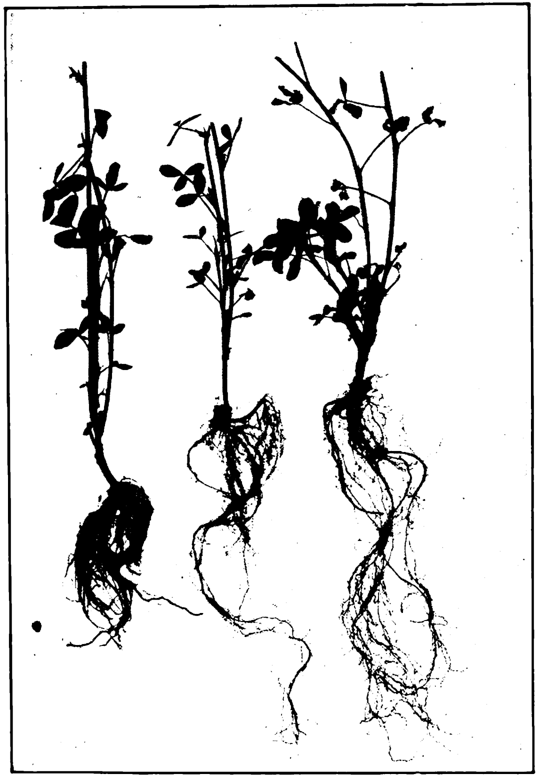

FIG. 1.—ROOTED CUTTINGS OF PERUVIAN ALFALFA READY FOR TRANSPLANTING TO PERMANENT NURSERY ROWS

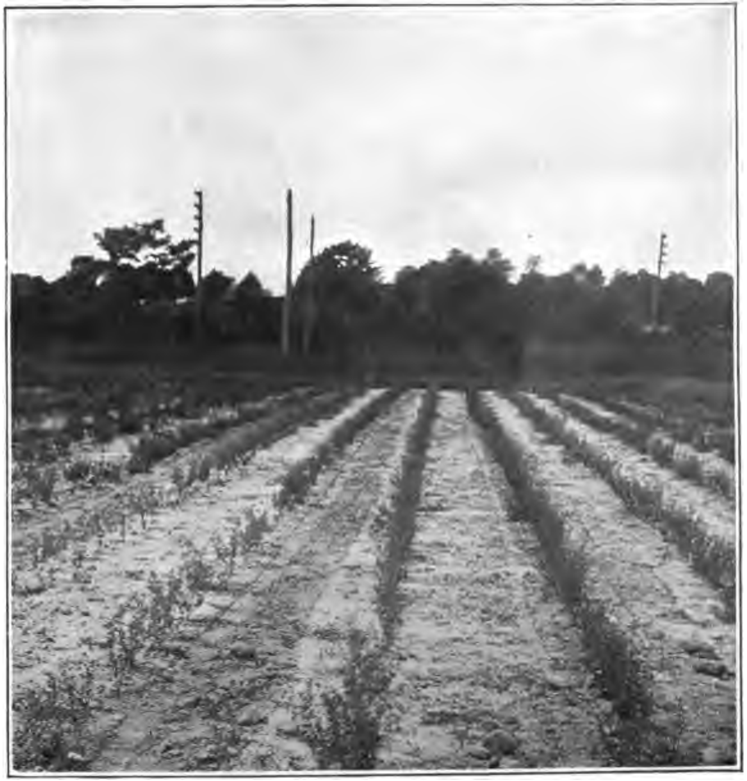

FIG. 2.—PLANTS FROM CUTTINGS OF PERUVIAN ALFALFA IN PERMANENT NURSERY ROWS.

No losses resulted on one occasion in the transfer of 1,800 plants to the permanent nursery rows 5 miles distant. The tops were cut back to 6 inches in height before being removed from the pots in the cold frames. (See Pl. III, figs. 1 and 2.)

APPLICATION OF THE METHOD TO PRACTICAL PLANT-BREEDING PROBLEMS.

In connection with establishing new varieties of such leguminous forage plants as alfalfa and clover it is sometimes desirable to start with a strain from a single individual, or at best from a limited number of individuals. This is the case where an especially promising form is confined to so few plants that the problem of increasing the stock for further tests and possible introduction is a serious one. In work of this kind many difficulties have heretofore been encountered. The seed selected from a promising set of individuals in an ordinary nursery or testing plot may have as its male parents plants of all of the strains in the series under test, a circumstance which works against the fixing of the strain along the desired lines.

This promiscuous parentage can usually be avoided only by keeping the remainder of the plants clipped to prevent flowering. This is not practicable in case other strains are being developed at the same time. While it is possible to isolate several hundred plants so that the danger of outside pollination is for the most part eliminated, yet with a few plants this is much less satisfactory, as there is not the protection of numbers which a considerable area of plants of one strain gives. The several hundred plants which can readily be produced from the selected individuals during the winter can be isolated by transfer to a considerable distance from other plants of the same or closely related species. It is possible that a considerable area could be practically isolated by lateral screens to confine the fertilizing insects temporarily to the plants in question. Under these conditions the presence of great numbers will make it probable that the bulk of the seed secured will have the selected individuals for its male parents.

The quantity of seed procurable from a few plants is usually so small that several seasons are required to obtain sufficient stock for even the preliminary tests of the new strain under field conditions. But by using cuttings it is quite practicable to produce in the greenhouse as many plants from one individual during the first winter as would be expected in at least two years from seed. Therefore this method results in a considerable shortening of the time required to get the seed of any one selected strain in sufficient quantities for field tests.

In practical selection work where strains resistant to cold, drought, or disease are being developed, natural selection will weed out the undesirable plants. In these cases the method suggested by Hays[a] is most practicable. In case, however, the selections are being made along different lines, as for yield, leafiness, or composition, there can be no natural elimination of the undesirable individuals. Artificial elimination in many cases is tedious, as, for instance, when selection for composition is in progress. The method here described will enable fixed strains to be secured in a much shorter time than where the seed is influenced by pollen from inferior individuals.

In cases where there is at hand but a single individual of a given strain its possible destruction by accident may be guarded against by increasing the stock, as here suggested. If the preliminary tests show it to be of probable value, the question of seed production can then be considered.

The transplanting of matured alfalfa plants is difficult, owing to their great root development. It is much more expedient to make cuttings to the required number and transplant these to the desired location.

In experimental tests, such as fertilizer pot trials with single plants, it is well known that the individual variations of the different plants utilized is a varying factor, for which it is difficult to make corrections. This factor is practically eliminated where the plants under test are produced by cuttings from a single individual. It is suggested that in fertilizer tests, for instance, where pots or even small plots are used, the experiments can be rendered less liable to error by utilizing freshly rooted cuttings of a single individual for the entire series of experiments.

In view of the bearing which the self-fertility of a given species has upon the application of the method to starting a strain from a single individual, a list of self-sterile and self-fertile plants is here given. This list is from Kirchner,[b] based in part upon his own work and, in part, upon that of others. Those plants listed as self-sterile failed to set seed when the inflorescence was bagged, while the self-fertile species produced seed when similarly covered.

Self-sterile.—Medicago sativa, M. falcata, Trifolium pratense, T. hybridum, Vicia cracca, V. angustifolia, V. villosa.

Self-fertile.—Melilotus alba, Medicago carstiensis, M. denticulata, Trifolium repens (slightly), T. incarnatum (slightly), Ornithopus sativus, Cicer arietinum, Vicia sativa, V. faba, Lens esculenta, Lathyrus sativus, L. tingitanus, Pisum sativum, Glycine hispida, Phaseolus vulgaris, Vigna sinensis.

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[a] Hays, W. M. A Method of Breeding a Hardy Alfalfa. American Breeders' Association, vol. 1, 1905.

[b] Kirchner, Q. Ueber die Wirkung der Selbstbestäubung bei den Papilionaceen. Naturw. Zeitschrift für Land und Forstwirthschaft, parts 1, 2, and 3, 1905. Digest in Bot. Centralbl., Vol. XCVIII, No. 18, p. 449, 1905.

The behavior of any species under continued inbreeding will determine the minimum number of plants which can be utilized as the foundation stock for a given strain. It is, of course, impossible to start with a single individual in case it is absolutely sterile to its own pollen. It may be, however, that the differentiation incident to vegetative propagation permits the use of pollen of plants derived from the same individual. If this last condition does not obtain, the employment of at least two individuals is essential. These should, of course, be as nearly identical as possible with regard to the desired characteristics.

The legumes are variable in respect to self-pollination, and unfortunately there still remains a great deal of work to be done in this direction, as many of the early experiments were not performed under as rigid conditions as might be wished. It is probable that many flowers failing to set seed when bagged fail not because they are sterile to their own pollen, but because of abnormal conditions incident to the bagging. A series of experiments is in progress to determine whether a number of the species of legumes usually regarded as self-sterile are not to a certain extent self-fertile, at least to pollen from other portions of the same plant or from another plant produced from a cutting from the same individual.

B. P. I.—261.

THE CONTROL OF TEXAS ROOT-ROT OF COTTON.[a]

By C. L. SHEAR, *Pathologist*, and GEORGE F. MILES, *Scientific Assistant in Pathology.*

INTRODUCTION.

Root-rot, or the so-called "dying" of cotton, is each year becoming a more and more serious enemy of the cotton grower in Texas and other parts of the Southwest. It has not yet been found east of Texas, but it is likely to spread gradually eastward. The extent of its damage to the cotton crop during the past season (1906) was apparently greater than ever before. It has been estimated that the total loss caused by this disease in Texas last year was about $3,000,000. During seasons favorable to the development of the parasite it increases its area of destruction quite rapidly. Some cotton planters have expressed the opinion that this disease is at present a more serious menace to the cotton crop of Texas than the boll weevil.

Root-rot is not restricted to cotton, but attacks a large number of other cultivated and wild plants.

CAUSE OF ROOT-ROT.

The disease has been attributed by planters to a variety of causes. Our investigations have shown, however, that it is primarily due to a fungous parasite which lives and spreads in the soil. This fungus is known as a species of Ozonium and is most prevalent and injurious in the Houston clay or black waxy soils of the Southwest. Under favorable conditions of temperature and moisture, the fungus attacks the roots of the cotton plants, destroying the rootlets and external surface of the roots and also invading the fibro-vascular system, thus causing the plants to suddenly wilt and die. This organism grows best where the aeration of the soil is poorest. The disease may be easily recognized by the sudden wilting and dying of the plants and the presence on the roots of dirty yellowish strands or a thin weft of the fungous filaments.

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[a] The results of the field experiments conducted by Doctor Shear and Mr. Miles last season (1906) were so promising that it is deemed desirable to present them to cotton growers at once. Further time will be required to complete the investigations and demonstrate more exactly the value of the method recommended.—B. T. GALLOWAY, *Pathologist and Physiologist, and Chief of Bureau.*

EFFORTS TO CONTROL THE DISEASE.

Our investigation of this disease, including the tests of possib methods of prevention or control, is not yet complete. A conside able variety of tests has been made in the application of vario fungicides and other chemicals and fertilizers to the soil, and attemp have also been made to secure by selection a race or variety of cott that might be immune or show some degree of resistance to the di ease. Neither of these lines of investigation has yet given promise success.

ROTATION OF CROPS.

It is generally known to planters familiar with root-rot that it do not affect grasses and grains, and when such crops are grown upo infected land for a few years the succeeding cotton crop is not likel to suffer so badly. The beneficial results from such rotations alon are, however, not always uniform or satisfactory.

AERATION OF THE SOIL BY DEEP PLOWING.

Field and laboratory investigations, coupled with the experie of practical growers, have led the writers to conclude that lack proper aeration of the soil is one of the most important factors fav ing the development of the root-rot fungus. Deeper plowing th that usually practiced in ordinary cultivation methods improves t aeration of the soil and was therefore tried.

Three series of experiments were conducted, consisting of (1) de fall plowing, the land being plowed to a depth of 7 to 9 inches December 7 and 8, 1905, (2) deep spring plowing, and (3) spri subsoiling.

DEEP FALL PLOWING.

The experiment in deep fall plowing was carried on near Luli Tex. An area was selected where the cotton was nearly all kill by the root-rot during the previous season. Three acres of this fiel were plowed 7 to 9 inches deep; the remainder was given the ordinar preparation and cultivation, being simply bedded up with a "middl buster" in the spring. The cotton on both plats was planted a the same time and treated in the same manner during the season On October 25, 1906, by an actual count of the plants in 15 rows o each plat, representing the average condition, only 12 per cent o the plants on the deep-plowed plat were found to be dead, while o the check plat adjoining, which had received ordinary preparation 96 per cent of the plants had been killed by the disease.

DEEP SPRING PLOWING AND SUBSOILING.

The results of the deep spring plowing and subsoiling were not so satisfactory, though there was a very noticeable benefit from this treatment. The plants on the subsoiled land showed much less rot than those on the land which was plowed deep. The cotton was noticeably larger and more productive on all the treated plats, and especially on that which was subsoiled.

The accompanying illustration of our experimental plat at Petty, Tex., from a photograph taken October 19, 1906, shows on the left root-rot-infected land treated by spring subsoiling and on the right the check plat which received ordinary preparation. The contrast was not so great, however, throughout the whole area. It was impossible to obtain satisfactory photographs of the plats treated by deep fall plowing, as the leaf worm had destroyed the foliage.

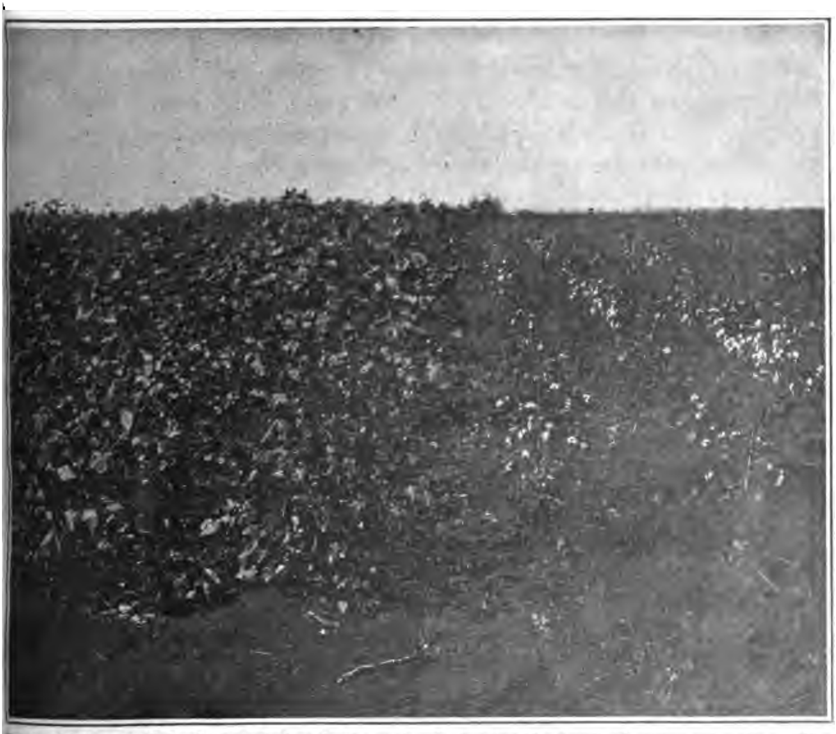

FIG. 3.—Cotton field badly infested with the root-rot, showing the result of spring subsoiling. The plat at the left, subsoiled, shows the cotton mostly alive, and the plat on the right, prepared in the ordinary way, shows the cotton nearly all dead.

TREATMENT RECOMMENDED.

The benefit derived from deep fall plowing is so remarkable that it seems desirable to call the attention of cotton growers to this method of controlling the root-rot. The deep fall plowing should be combined with rotation of crops, using, for two or three yea previous to planting cotton on the land, some of the grasses or grai best adapted to the requirements of the particular locality. Th course has proved most practicable and successful in combating th disease.

In order to attain success by this method the plowing must very thoroughly done and at the proper time. Good results ca not be secured unless the land is plowed to a depth of at least inches, and 9 inches would be still better. This work can not done with the small plows in general use by cotton planters. good disk plow or a 12 to 14 inch plow of the ordinary form mu be used. In the experiments of the writers the plowing was do early in December. We believe it would be better to do it i November, as the soil would have a greater opportunity to beco aerated; but if it is impossible to do the plowing in the fall should be done during the winter or early spring.

P. I.—274.

THE HISTORY OF THE COWPEA AND ITS INTRODUCTION INTO AMERICA.[a]

By W. F. WIGHT, *Assistant Botanist, Taxonomic Investigations.*

INTRODUCTION.

The purpose of this paper[b] is to give a brief history of the introduction of the plant known as the cowpea (*Vigna unguiculata*) into America, to establish as nearly as possible the time at which it was introduced, and to ascertain the region to which it is native.

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[a] Although the cowpea is the chief leguminous crop of the southern United States, the most diverse and often erroneous ideas prevail in regard to its geographic origin and the time and means of its introduction into American agriculture. It has been maintained by some, for example, that it is a native of tropical America; by others, that it was brought from Africa by the negro slaves, and by still others that it was introduced by the United States Department of Agriculture.

Because of the bearing of the question on certain introduction and breeding experiments with cowpeas, Mr. A. J. Pieters, then in charge of the seed introduction and distribution work of the Department, started an inquiry into the subject, intrusting the work to Mrs. K. S. Bort, who made extensive extracts from the literature of cultivated plants. So many questions arose, however, requiring the consideration of a botanist trained in the critical discrimination of plants and with a wide knowledge of botanical literature, that Mr. W. F. Wight was assigned to the task. He has made a thorough investigation of the history of the cowpea, and in the accompanying paper has brought forward proofs of the principal points in that history, namely, that the cowpea is a native of the Afghanistan region; that it was introduced into the West Indies over two hundred years ago, and that it subsequently was brought to the American mainland, gradually extending northward until, about 1797, it reached the latitude of the Potomac and attracted the attention of such a keen agriculturist as Washington himself.—FREDERICK V. COVILLE, *Botanist in Charge of Taxonomic Investigations.*

[b] The author wishes to acknowledge his indebtedness to Mr. Frederick V. Coville for Latin and Greek translations and for many suggestions; to the Chinese Legation for translation from the Chinese; to Mr. S. Stefansson, of the Library of Congress, for translation of Arabic; and to Mr. C. M. Mansfield, of the Bureau of Plant Industry, for photographs.

The conclusions which have been drawn are, briefly, that it was introduced into the West Indies during the latter half of the seventeenth century and probably reached the mainland during the first half of the eighteenth century; that it is a native of India and the region northwestward to the southern part of the trans-Caspian district; that its cultivation in that region is of ancient date; that its cultivation extended to China at a very early period; that it was known in Arabia and Asia Minor as early as the beginning of the Christian era, and was cultivated in at least one of the countries of southern Europe at about the same time, but that its introduction into central Europe was of much later date and entirely independent of its introduction into southern Europe.

HISTORY.

The nativity of several economic plants that have been in cultivation for a very long period is extremely difficult of determination. This difficulty is especially great in the case of the cowpea (*Vigna unguiculata*), because of its similarity to some other leguminous plants likewise in cultivation for several centuries, and the vague way in which these plants were described or alluded to by early authors.

It is evident from the statements of these authors that more than one bean-like plant was in cultivation in southern Europe before the discovery of America. It may be inferred also that at least one of these plants bore a close resemblance to the common or kidney bean[a] (*Phaseolus vulgaris*), since this species was introduced into Europe without apparently receiving the attention that a plant more unlike any known to them would have attracted. The statements regarding the origin of maize, for instance, are much more definite than those concerning the species of beans. Many of the botanical authors who wrote during the century following the discovery of America and the introduction of American species into Europe, like their predecessors, sought to identify the beans cultivated at the time they wrote with the bean-like plants described by Theophrastus and Dioscorides. This tendency is doubtless at least partly responsible for their failure to distinguish clearly the species then cultivated. De Candolle, in the "Origin of Cultivated Plants," while doubting the identity of *Phaseolus vulgaris* with any of the plants known to the ancients, after discussing the origin of the words applied to *P. vulgaris* in several European languages, says (p. 339): "Nevertheless, the *dolichos* of Theophrastus has been definitely referred [by other authors] to the *scarlet runner* [*Phaseolus coccineus* (*P. multiflorus* Lam.)], and the *fasiolus* to the dwarf haricot [*Phaseolus vulgaris*] of our gardens * * * . I can only say it may be so." Again (p. 347): "*Lobion* in Dioscorides is the fruit of *Ph. vulgaris*, at least in the opinion of commentators."

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[a] In this paper the expression "the common bean" is not used to designate any particular one of the many garden varieties of *Phaseolus vulgaris*, but is applied to all the forms of the species. The term "kidney bean" is used by the English and "haricot bean" by the French in the same sense.

De Candolle, however, apparently did not examine very carefully the evidence of the American origin of these plants. The early accounts of discovery in America contain references to leguminous plants which indicate that they were extensively used by the natives of the New World.

Hariot, 1588, "A Brief and True Report of the New Found Land of Virginia," mentions two kinds: One, "Okindgier, called by us *Beanes*, because in greatness and partly in shape they are like to Beanes in England; saving that they are flatter, of more divers colours, and some pide. The leafe also of the stemme is much different." The other plant, "Wickonzowr, called by us *Peaze*, in respect of the beanes for distinction sake, because they are much less; although in form they little differ; but in goodness of taste much, and are far better than our English peaze." Captain John Smith, 1612 (Workes, 62), writes: "They plant also pease they cal Assentamens, which are the same they cal in Italye, *Fagioli*. Their Beanes are the same the Turkes cal Garnanses, but these they much esteeme for dainties."[a] The same author, 1616 (Works, 207), in a description of New England, mentions "beans and pease" among the "hearbes and fruits," but gives no descriptions. Josselyn, 1675 (Voyages, 73–74), distinguished four kinds of beans or peas, "French beans; or, rather American beans. The herbalists call them kidney-beans, from their shape and effects; for they strengthen the kidneys. They are variegated much—some bigger, a great deal, than others; some white, black, red, yellow, blue, spotted; besides your *Bonivis*, and *Calavances*, and the kidney-bean that is proper to Ronoake. But these are brought into the country; the others are natural to the climate." Lawson, 1714 (History of Carolina, 130, 131), mentions several kinds of "pulse" as "bushel bean," "Indian rounceval, or miraculous peas," "bonavis," "calavancies," and "nanticokes." He also says "the kidney beans were here before the English came, being very plentiful in the Indian corn fields." Brickell, 1737 (Natural History of North

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[a] Gray and Trumbull, 1883, American Journal of Science, 26: 132, think these names are confounded. "*Garvance* was the French name of the Chick Pea (*Cicer arietinum*), the Spanish *garbanzo;* and it is not probable that the Turks' gave this name to any kind of beans; while *fagiuoli* was the Italian equivalent of Latin *phaseoli.* Strachy's Virginian vocabulary gives *assentamens* (and otassentamens) for 'pease,' and *peccatoas, peketawes,* for 'beans.'"

Carolina, 16, 17), describes the beans of the country in the following language:

> There are several sorts of Pulse in this Province; and first, the ***Bushel Bean*** so called from producing a Bushel of Beans or more from one that is Planted they are a Spontanious product in *Carolina*, and are Set in the Spring roun Arbours, or near long Poles set in the Ground for that purpose, where the make a good Shade to sit under in the extremity of hot Weather; they continue Budding, Flowering, and Ripening all the Summer, until the approac of Frost, which prevents their farther Growth, and so dye; They clim prodigious high, and their Stalk is about the thickness of a Man's Thumb the Pod grows like the *Kidney Bean*, but the Bean is flat, white, or mottled with a purple Colour: They are extraordinary good, and well relished Pulse either by themselves or with Meat.
>
> The *Indian Rouncival*, or *Miraculous Pea*, so called from their long Pod and great Increase. These are a late Pea, and require a pretty long Summe to ripen and bring them to Perfection, they are a good Pulse, and in grea plenty all over this Province with *Christians* and Indians.
>
> The *Bonavis* is another kind of *Pulse*, and yields a great Increase, it doth not require so long a Summer to ripen as the former, they grow like *Kidney Beans*, and are very plenty in this Province.
>
> The *Calivances* are another kind of *Pulse*, resembling the former, but are no so flat, they are in great plenty in most of the Plantations amongst the Indian Corn. These and the *Bonavis*, afford two Crops in the Year, and are generally ripe and in full perfection in six Weeks time.
>
> The *Nanticoacks* are another kind of *Pulse*, and resemble the *Calivances*, and are in great plenty all over this Province.
>
> There are several other kinds of *Pulse* in this Province that we have no Name for, which are well known amongst the *Indians*, and are excellent Food
>
> The *Kidney-Bean*, is likewise here in great plenty growing for the most part in every Corn-Field. The Indians had these four Sorts of *Pulse*, *viz.* the *Bonavis*, *Calivances*, *Nanticoacks*, and *Kidney-Beans*, and several other sorts long before the Arrival of the *Europeans* amongst them; which Report I have had affirmed several times, not only from the *Christians*, but likewise from the *Indians* in these Parts.

These references and many others given by Gray and Trumbull 1883 (American Journal of Science, 26: 130–138), and by Sturtevant 1887 (American Naturalist, 21: 327–331), certainly justify those authors in the conclusion that *Phaseolus vulgaris*, *P. coccineus*, and *P. lunatus* are natives of the New World. Koernicke, 1885 (Verhandl. Nat. Hist. Rhein. & Westphal. Correspondenzblatt, 136), also arrived at the same conclusion in regard to *P. vulgaris*. The recent discovery of seeds identified as *P. vulgaris* in the remains of the mound builders in Ohio and of the cliff dwellers in New Mexico[a] affords evidence additional to that presented by the above authors of the nativity of that species. But among all the references given there is no positive evidence that any species of Dolichos or Vigna was in cultivation by the Indians for at least a hundred years after the first English settlement. The authors of the eighteenth century record a greater number of legumes than the authors of either the sixteenth or seventeenth centuries, and there are frequent references in the literature of that period to the introduction of seeds from the Old World. Not a single species of Dolichos is known except in a cultivated state in North America north of Mexico, and Hemsley does not enumerate any in the Biologia Centrali-Americana. Only one species of Vigna, *V. repens*, now found spontaneous throughout the Tropics, has the appearance of being indigenous to either North or Central America, while about 10 species of Phaseolus are known in a wild state in North America, and Hemsley enumerates 41 in the Biologia Centrali-Americana for Central America.

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[a] Wittmack, 1905, Trans. Acad. Sci. St. Louis, 15: 14.

The time at which important American food plants were introduced into England is also significant in regard to the origin of these plants. The following dates are given on the authority of Aiton (Hortus Kewensis, 1789): *Zea mays* was cultivated in 1562; *Nicotiana tabacum* before 1570, but the exact date is apparently not known; *Lycopersicon lycopersicum* was cultivated in 1596; *Phaseolus vulgaris* in 1597, and *P. coccineus* (*P. multiflorus* Lam.) in 1597. The date given for *P. lunatus* is 1779, but the figure and description of Gerard's third kind (Gerard, 1597, Herbal, 1039), correspond very closely to the so-called sieva type of *P. lunatus*, and it is possible that it had been introduced at an earlier date and, not meeting with favor, disappeared, but there is no evidence that *Vigna unguiculata* and *Dolichos sesquipedalis* were introduced into England before 1776 and 1781, respectively. With one possible exception, therefore, plants of undoubted American origin were cultivated in England more than a century and a half before *Vigna unguiculata* or *Dolichos sesquipedalis*. This would scarcely have been the case if the two last-named species had been cultivated in America for a long period, as the first-named were.

Of the two kinds distinguished by Hariot in 1588, the one called "Peaze" is without doubt the kidney bean, as it is called "Peaze, * * * for distinction sake * * * though in form they little differ" from the bean except in size. The latter is compared with the English bean (*Vicia faba*) in size and partly in shape, and is either a large form of kidney bean or the Lima bean. If the words "Fagiole" and "Garnanses" or garvanses are confounded by Smith, the "pease" which he mentions probably refers to a species of Lathyrus or Vicia, and the "Beanes" to the common kidney bean. There can be little doubt that "Garnanses" is a corruption of the Spanish *garbanzo*, French *garvance*. It has also been written "garavance," "garvancos," and "gravances." The writer has been unable to find this word used in Europe for any other plant than the chick-pea (*Cicer arietinum*), and although the introduction of seeds into America began as early as the second voyage of Columbus, it is improbable that the cultivation of the chick-pea could have been introduced among the Indians of the United States as early as 1612, and it is doubtful whether it was ever cultivated by them.

There is no evidence that it was cultivated to any extent by the colonists, though it was introduced some time previous to 1790. The name was probably applied by Smith to some plant with a superficial resemblance to the chick-pea, perhaps a vetch. There is at least no evidence that the plant called " garnanses " was a species of either Vigna or Dolichos. The name " calivance " was applied by Sloane, 1707 (Natural History of Jamaica, 1: 183), to the cowpea, and this word is believed to be a corruption of " garbanzo." The forms given in Murray (English Dictionary, under Calavance) are, " garvance," " caravance," " callavance," " callevance," " callvanse," " kalavansa," " callivancy," " callivance," " calavance." The earliest use of the word " calavance " that the writer has been able to find is by William Hughes, 1672 (The American Physician, or a Treatise of the Roots, Plants, Trees, Shrubs, Fruit, Herbs, etc., 17, 18), where he writes concerning " Calavance, or Calavances: "

> These Pease have long and small stalks, of a brownish green colour, branched and spread upon the ground (unless they be supported by Props) much after the same manner of our Field-pease; the leaves shoot forth at several places, set one against another, of a more yellowish green colour than ours in *England* are: They have also towards the top, clasping Tendrils, as ours have: The Cods are pretty long, wherein are small Pease of the bigness of our Vetches, but long; or of the fashion of a Kidney-bean, and very smooth; outwardly, of a dark red colour; neither are they uneven when they be dry.
>
> They grow in many places in *America*, as in *Jamaica*, at Colonel *Barington's* Plantations, at Ligance, at Portamorant, etc.
>
> They are planted at any time, and flourish all the year; of which the Husbandmen or Planters there, have five crops in two years.
>
> Some call them the *Indian Vetches*, some the *Indian Pease;* but those that are Inhabitants there, call them *Calavances*, or *Calievancie.*

The plant described by Hughes is certainly a plant with pinnate leaves and tendrils, like the chick-pea, but Sloane, 1696 (Catalogus Plantarum Jamaica, 71), cites " Calavance or calavances of Hughes, p. 17 (?)," under *Phaseolus erectus major*, which is a cowpea. The same author, 1707 (Natural History of Jamaica, 1: 183), under *Phaseolus erectus major*, says " Callavance Jamaicensibus dictus," without any indication of doubt. It would appear from these facts that the word was originally used in America to designate a vetch-like plant and that its application to the cowpea by Sloane was an error. Several authors subsequently adopted Sloane's usage of the name, and it is preserved at the present day in the form "galavant" as the name of one of the varieties of the cowpea.

The four kinds mentioned by Josselyn, 1675 (Voyages, 73–74), are "kidney-beans," "bonivis," "calavances," and the "kidney-bean that is proper to Ronoake."

Bonivis is clearly a corruption of Italian *Buona vista*, and Hughes, 1750 (Natural History of Barbadoes, 216), writes "*Buona Vista*, commonly called *Bonny-vis*." Its earliest use in America appears to be by Richard Ligon, 1657 (A True and Exact History of the Island of Barbadoes, 22, 24), "Maies, and Bonavists, planted between the boughs, the Trees lying along upon the ground; so far short was the ground then of being cleared." No description is given by which the name can be identified with a particular species, and its application can only be inferred from its later use by other authors. Sloane, 1696 (Cat. Pl. Jam., 67, 68), and 1707 (Nat. Hist. Jam., 1:177), uses bonavist for *Dolichos lablab*. The "Buona vista" of Hughes, 1750 (Nat. Hist. Barbadoes), is also certainly *Dolichos lablab*. Wherever the word "bonavist" in its various forms occurs with an identifiable description it refers to *Dolichos lablab*. Josselyn's "calavances," like that of William Hughes, is probably a plant with pinnate leaves. Certainly no variety of *Vigna unguiculata* then known would mature seeds in New England. The "kidney-bean that is proper to Ronoake" may be either the Lima bean, the scarlet runner, or one of the numerous varieties of the kidney bean.

The "bushel bean" of Lawson is probably *Phaseolus lunatus*. Sturtevant, 1885 (Amer. Nat., 19:454), has suggested that the "Indian rounceval, or miraculous peas," may have been *Dolichos sesquipedalis*, but it would have been more natural for an Englishman to have applied the term to a plant more nearly resembling the English rounceval. Lawson's "bonavis" is doubtless *Dolichos lablab*, but "calavancies" and "nanticokes" are scarcely identifiable, though the latter is probably one of the various forms of the kidney bean. Brickell gives nearly the same description of bushel bean and Indian rounceval as found in Lawson; in fact, the wording is so familiar that it is without much doubt copied from the earlier author. There is less doubt, however, regarding the "Calivances" of Brickell. They resembled the bonavis, except that they were not so flat. This clearly refers to some other plant than a Vicia or Lathyrus, and though it can not be identified from the descriptions, it must be either a form of *Phaseolus vulgaris* or perhaps the red-seeded form of *Vigna unguiculata*, the "callavance" of Sloane.

Jamaica was captured by the British in 1655, and possession was confirmed by treaty in 1670. William Hughes (The American Physician, etc., published in 1672), describes several plants cultivated in

Jamaica, but does not include *Vigna unguiculata*, his calavance, as noted above, being a different plant. If *Vigna unguiculata* had been cultivated in Jamaica at that time it would probably have been mentioned with the other cultivated legumes Hughes described. Sloane visited the island in 1687, remaining fifteen months, and found both the red and white seeded forms, and it is therefore very probable that they reached Jamaica some time between the years 1672 and 1687. Any plant that had been found valuable in Jamaica would no doubt soon be tried in the southern colonies, for the early accounts of the colonies indicate that they frequently obtained seeds of new plants for trial. The Georgia colony even sent a man to the Spanish West Indies to secure new plants (Francis Moore, 1744, A Voyage to Georgia, Georgia Historical Society, 1840, 1:99). It is therefore possible that even the calavance of Lawson, 1714, is *V. unguiculata.* The statement of Brickell, 1737 (Natural History of North Carolina), that these plants were in America before the arrival of the Europeans can scarcely be taken seriously, for he makes it on the authority of the settlers and Indians who would easily confuse plants so similar in appearance as *Vigna unguiculata* and *Phaseolus vulgaris.* The exportations of peas mentioned by some of the early historians probably refer to English peas, as Lawson, 1714 (Hist. Carolina, 130, 131), says English peas " have been made trial of " and " yield very well."

The first unmistakable reference to the occurrence of *Vigna unguiculata* on the mainland of America appears in Romans (1775), Natural History of East and West Florida, 122, where the author says: " Pease, as they are here called but improperly, because species of the *Phaseolus* and *Dolichos* are meant, follow the maize in utility. It is well known that most people use them like European pease either green or dry, and some kinds, such as the small white sort, the bonavist, cuckolds increase, the white black-eyed pea, the white crowder, and many others, are undoubtedly at least as good." The " small white sort " is doubtless a white variety of the common bean; bonavist probably refers to *Dolichos lablab.* " Cuckolds increase " is applied by Patrick Brown, 1756 (Natural History of Jamaica, 292), to a species which he says resembles his seventh species, " Phaseolus erectus major," Sloane, which is *Vigna unguiculata.* Lunan, 1814 (Hortus Jamaicensis, 1:434), says the " cuckolds increase " " seems to be a species of *dolichos*, as does the bonavist." The white black-eyed pea is undoubtedly identical also with the black-eyed pea of Jamaica, another common form of *Vigna unguiculata.* The " white crowder " does not appear to be described by either Sloane or Brown. With the exception of the " small white sort " and the " white crowder " the names given by Romans were also given by Brown nineteen years earlier, and by Lunan thirty-nine years later, and the fact that the names "calavance," "bonavist," "cuckolds increase," and "black-eyed pea" all appear in the natural history literature of the West Indies earlier than they occur in the accounts of the American colonies indicates that they came from the West Indies to the mainland. Lunan, 1814 (Hortus Jamaicensis, 1:167), under "Dolichos" says: "Besides the above indigenous species, three exotic ones have been introduced, the lablab, of which arbours are made in the East; the *sinensis*, or Chinese dolichos; and the catjang, which is said to be cultivated for food in the East Indies."

The discussion given by Romans indicates that "pease" had been grown in the southern colonies for several years, long enough at least for their use to become "well known." In Virginia, however, there is evidence that *Vigna unguiculata* was not cultivated, at least to any extent, at so early a date. The correspondence of Washington affords interesting evidence of this fact. A letter dated Hyde-Park, Fairfax County, November 18, 1791, in reply to a circular letter sent out by Washington (Letters on Agriculture to Arthur Young and Sir John Sinclair, edited by Franklin Knight, 51, 1847), contains the following statement:

> As to pease, beans, potatoes, and turnips, our lands yield them very well, but as they are not raised for market in general I can not say what may be their average product per acre. It has ever appeared to me that if the farmers in Europe, who lay so much stress upon these articles in their writings, had our excellent substitute for them, Indian corn, they would only regard them as we do, for culinary purposes.

Washington was accustomed to growing seeds of new plants that might prove of agricultural value, and there are frequent references in his correspondence to seeds which had come from England or other countries and of which he wished the gardener to take particular care. The following are mentioned in Washington's correspondence, besides the staple crops of corn, wheat, etc.: Lucern, sainfoin, India hemp, buckwheat, furze, flax, white bent-grass, everlasting peas, and English field peas.

It was Washington's practice, sometimes, at least, to plant potatoes with corn, since in a rotation of crops recorded in "George Washington and Mount Vernon," edited by M. D. Conway, 287, 1889, "Indian corn, with intermediate rows of potatoes, or any root more certain or useful (if such there be) that will not impede the plough, hoe, or harrow in the cultivation of the corn," is given for one crop of the rotation. There is apparently no reference in any letter of Washington to the cultivation of peas or beans with corn. He used buckwheat as a green manure.

The first reference by Washington to the cowpea is in a letter to Landon Carter, of Cleve, dated Philadelphia, 27th February, 1797, in which he says: "I hope, as the season is approaching fast when the ground should be prepared for it, that you have informed Mr. James Anderson (my manager) in a letter directed to the care of the postmaster in Alexandria, at what time he may send for the peas you were so obliging as to promise me;" and the following from a letter of James Anderson to Landon Carter, which accompanied the above letter of Washington. "I have only to add to that wrote by the President—that the sooner you have 40 bushels of the White Indian pease, with black eyes—ready, you will the more oblige the President, I do not wish any of the small kind either the round kind called the Gentlemen pease, nor of the other small kind which resemble the large."

Jefferson, 1801 (Notes on the State of Virginia), makes no mention of peas or beans, although he enumerates the cultivated plants (p. 58), saying—

> Our farms produce wheat, rye, barley, oats, buckwheat, broom corn, and Indian corn. The climate suits rice well enough, where the lands do. Tobacco, hemp, flax, and cotton, are staple commodities. Indigo yields two cuttings. The silk-worm is a native, and the mulberry, proper for its food, grows kindly.
>
> We cultivate also potatoes, both the long and the round, turnips, carrots, parsnips, pumpkins, and ground nuts (Arachis). Our grasses are lucerne, St. foin, burnet, timothy, ray and orchard grass; red, white, and yellow clover; greensword, blue grass, and crab grass.
>
> The gardens yield musk-melons, water-melons, tomatos, okra, pomegranates, figs, and the esculent plants of Europe.

Beans and peas are not mentioned, and it may therefore be inferred that neither was at that time of sufficient importance in northern Virginia to be listed among the farm crops. A legume, probably *Vigna unguiculata*, was, however, cultivated in the cornfields to some extent in southern Virginia some years earlier than the publication of Jefferson's Notes.

Dr. James Greenway, of Dinwiddie County, Va., in an article on *Cassia chamaecrista* as a soil renovator (Transactions of the American Philosophical Society, 3: 226, 1793), says the "common cornfield-pea is far preferable to everything that I have seen tried for this purpose. Every farmer who leaves his pea vines on the ground, and does not in the accustomed manner, pull them up for fodder, must often have observed that they quickly moulder and fall to pieces; furnishing a covering to the ground, which readily unites and blends with it, in the manner mentioned of the bean" [i. e., *Cassia chamaecrista*].

A catalogue of the plants found growing near Lancaster, Pa., by Muhlenberg, 1793 (Transactions of the American Philosophical Society, 3: 157), in which cultivated and introduced plants are given, as well as wild plants, does not mention any Dolichos or Vigna. The cowpea evidently had not then reached that locality.

It may be seen from the facts presented that there is no evidence that *Vigna unguiculata* was one of the native beans of America. On the contrary, it appears to have been first introduced into Jamaica at some time between 1672 and 1687 and to have reached one or more of the southernmost colonies, probably from Jamaica, sometime after the latter date, but before 1737, and its use to have extended gradually northward until it reached the Potomac about 1790 or 1795.

Notwithstanding the confusion wrought by commentators seeking to identify *Phaseolus vulgaris* with one of the climbing plants of Theophrastus and Dioscorides, European botanical literature affords very convincing evidence of the Old World origin of *Vigna unguiculata.*

Phaseolus vulgaris appears to have reached central Europe about 1536, and many authors at once identified it with Dioscorides's Smilax kepaia, or, as translated into Latin, Smilax hortensis. The species is discussed by Brunfels, 1536 (Herb. Viv. Ic., 3: 130), and identified on the authority of Heironymus Tragus with Dioscorides's plant. Brunfels in his Exegesis omnium simplicium Dioscorides (Brunfels,[a] 1532, Herb. Viv. Ic., 2: 114), does not identify Smilax more than to say that, according to Barbarus, it is a kind of phaseolus, and it is evident that *Phaseolus vulgaris* was not known to this author when volume 2 of his work was written. Bock, 1546 (Kreuterbuch, 236), has a good colored figure of the kidney bean, and says it has lately come into Germany.

Matthiolus, 1588 (Opera, 341), says that phasioli are common in Italy, but he apparently confuses the dwarf form of *Phaseolus vulgaris* with the "phasiolus" of the ancients. No stipules are shown in his figure, and it is probably *Phaseolus vulgaris*. In the earlier editions of Matthiolus's works, which appeared while the author lived in Italy and southern Austria, no bean with "black-eyed" seeds is described among the various sorts of "phasiolus." In a later work, Matthiolus, 1565, Commentarii, 429, the dedication of which was written at Prague, and dated January, 1565, seeds with a black ring about the eye are described, but the figure is the same as in the work issued in 1558. In Camerarius's edition of Matthiolus, 1586 (De plantis epitome utilissima, 212), however, the figure of phaseolus is *Vigna unguiculata*. It is certain that a low-growing leguminous plant, resembling the dwarf form of *Phaseolus vulgaris*, was cultivated in the Mediterranean region of southern Europe before the discovery of America. Several of the ancient treatises on agriculture give cultural directions for such a plant. Many, if not all, of the botanical authors after Dioscorides mentioned phaseolus, and Albertus Magnus, who lived in the thirteenth century, used the word "faselus" for a plant which had seeds with "a black spot at the hilum." Caesalpin, 1583 (De Plantis, 238), also described "phaselus" as having seeds with a black pupil.

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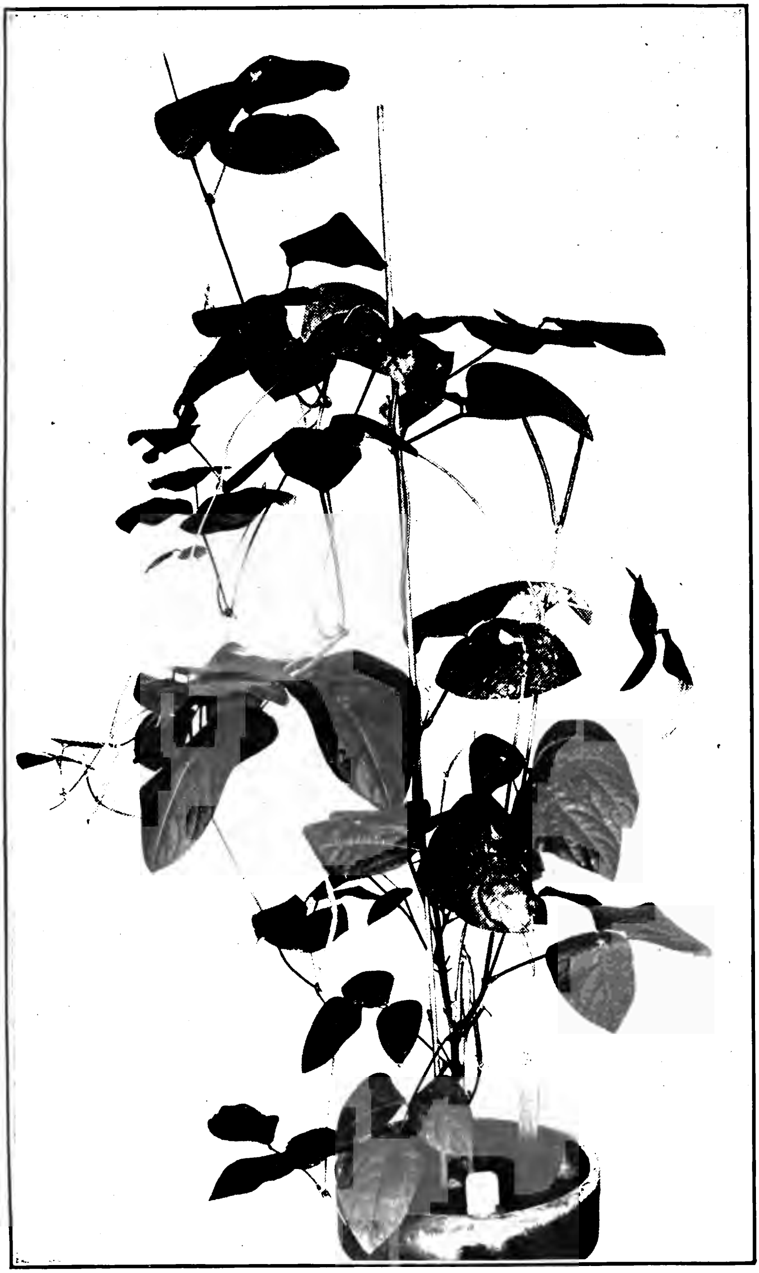
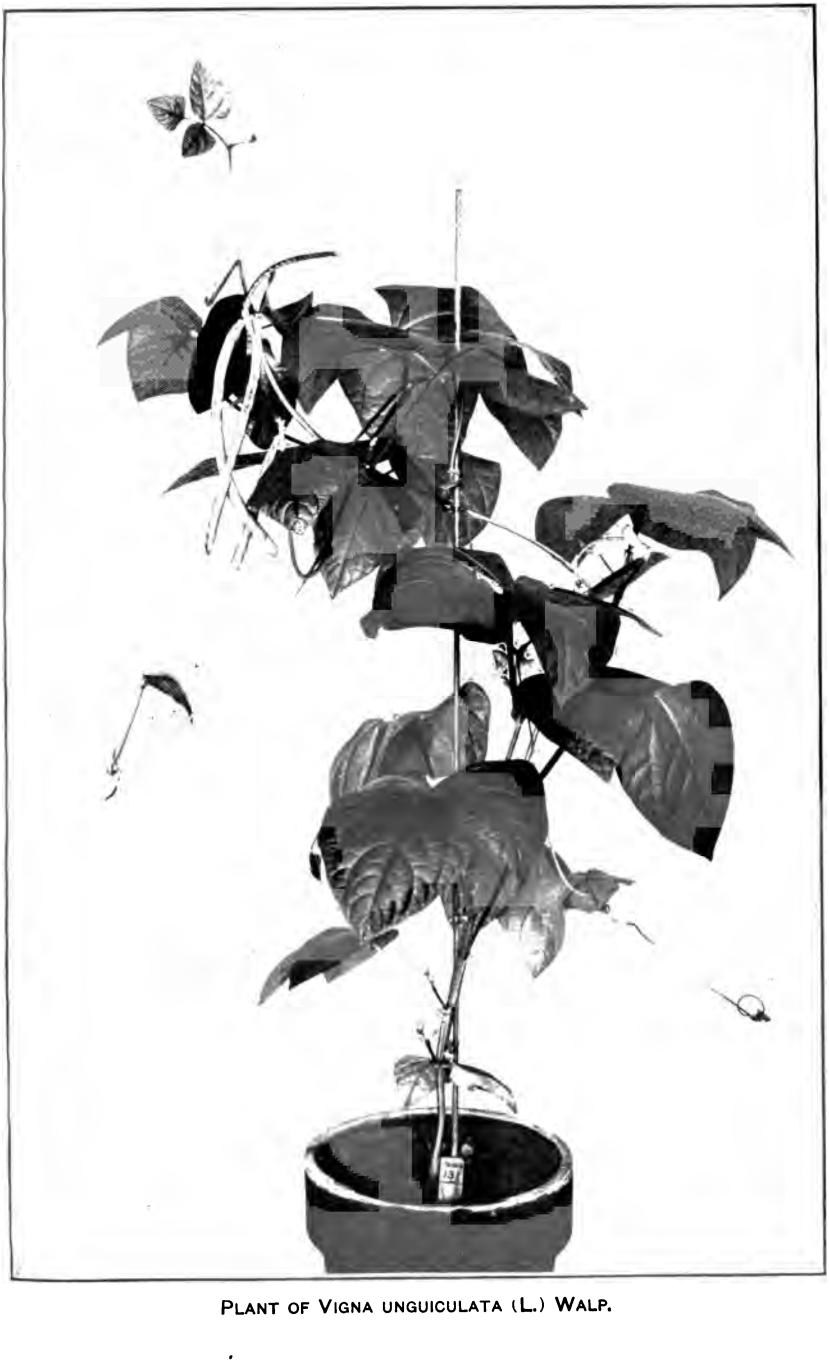
[a] The edition of this work published in 1536 was the one consulted.

Koernicke, 1885, Verhandlungen des naturhistorischen Vereins der preussichen Rheinlande, Westfalens und des Reg.-Bezirke Osnabrück, Correspondenzblatt, 136, maintains that the phaseolus of Dioscorides and the phaseolus cultivated in Italy before the discovery of America were the same species, "*Vigna sinensis*," and that the "Smilax kepaia" of Dioscorides was likewise that species, but a climbing form. Koernicke states that a work of the year 1415, by Rinio, a Venetian physician, contains a colored illustration of "Faseolus," and he identifies this as *Dolichos melanopthalmus* DC. He says also that in both Codices of Dioscorides of the fifth century after Christ, which illustrate the plant named phaseolus, the figures are likewise the low form of *Vigna unguiculata*, while for Smilax kepaia an illustration is wanting. Koernicke, however, believes *Dolichos melanopthalmus* DC., *D. monachalis* Brot., *D. lubia* Forsk., *D. sesquipedalis* L. to be low forms, and *D. catjang* L., D. *sinensis* Stickman, and *D. tranquebaricus* Jacq. to be climbing forms of the same species. Baker, 1879 (in Hook. Fl. Brit. India, 2:206), gives *V. sinensis* as the climbing and *V. catjang* as the low form. Koernicke says that the variation in the seeds is not greater than in *Phaseolus vulgaris*, and that dried plants in the Berlin Herbarium show no specific differences. *Vigna sinensis* (*Dolichos sinensis* Stickman) on the basis of priority is adopted by Koernicke as the correct name of the species, but he apparently overlooks the fact that *Dolichos unguiculatus* L. (*Vigna unguiculata* (L.) Walp.) is still earlier. Koernicke gives central Africa as the original habitat of the species. *Dolichos sesquipedalis*, the asparagus bean, is considered a distinct species by most authors, and the writer can not agree with Koernicke that all the other names apply to the same species or that central Africa is the home of any of them. It is true that the habit of growth, whether low or a climbing form, is of no specific value, for *Vigna unguiculata* at least seems to vary in this respect.

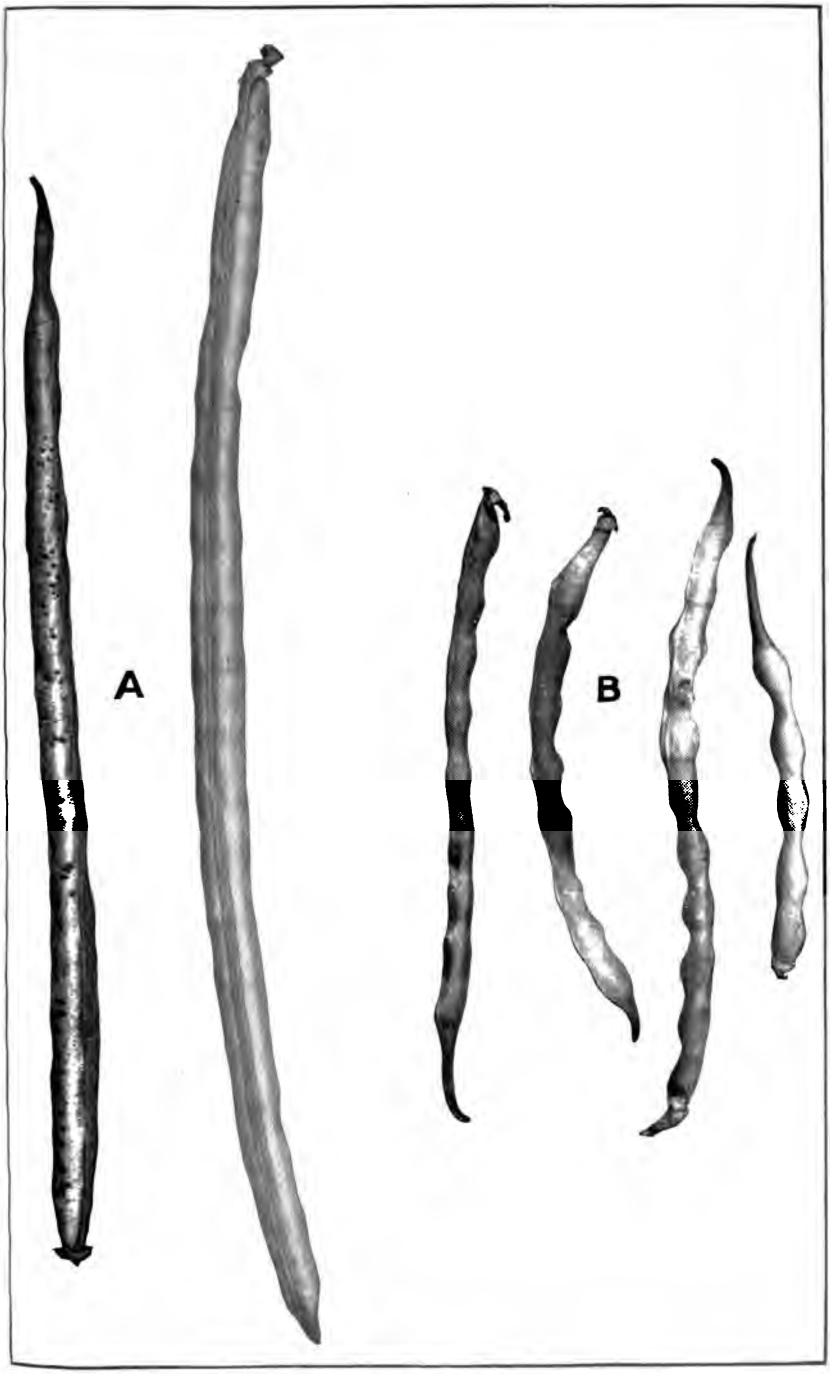
The color of the seeds likewise fails as a distinguishing specific character. *Dolichos unguiculatus* L. was founded on specimens grown in the garden at Upsala, but came to Linnæus from Barbados. *Dolichos sinensis* was based on *Dolichos sinensis* or *Katjang Sina* of Rumphius, and the figure in Rumphius Herbarium Amboinense shows a climbing plant with two-flowered racemes and pendulous pods. *Dolichos catjang* is likewise based on a species of Rumphius, *Phaseolus minor* or *katjang poeti*. The figures of this



PLANT OF VIGNA CATJANG (BURM.) WALP.



PLANT OF VIGNA UNGUICULATA (L.) WALP.



PODS OF COWPEAS.

A.—*Vigna unguiculata.* (Natural size.) B.—*Vigna catjang.*

species shows a plant with the racemes two or three flowered, but with the pods at maturity smaller and erect, or nearly so, and with smaller seeds. A species grown in the greenhouses of the United States Department of Agriculture shows similar characters, the pods remaining erect until full grown, although they become pendent at maturity. The pods are also conspicuously torose at maturity. This species is *Vigna catjang* (Burm.) Walp. (Pl. I and Pl. III, B). Practically all of the varieties commonly cultivated in America belong to *Vigna unguiculata* (L.) Walp. (*V. sinensis* (Stickman) Endl.), the species with larger seeds and larger pods which usually become pendulous when half their mature size or sometimes even earlier, and which are only slightly constricted between the seeds (Pl. II, and Pl. III, A). Forskal, 1775 (Fl. Aegypt-Arab., 133), described *Dolichos lubia* as having peduncles racemosely spicate at the apex and the flowers crowded, and it may therefore be inferred that the racemes were several-flowered. The pods were described as erect. The color of the seeds is not mentioned by Forskal, but Delile, 1812 (Plant. Cult. en Egypt, 14), says they were white, with a black point at the eye. Koernicke says the "ring about the navel is pale red," and the seeds labeled *D. lubia*, recently received from the Muséum d'Histoire Naturelle, Paris, are quite small, red, with a black ring at the hilum. The varieties of *Vigna unguiculata* commonly cultivated in America seldom vary from the few-flowered character of the raceme and, at maturity, pendulous pods. Delile says *Dolichos lubia* is known also in Syria, Persia, and India, but there is but one other modern author who has applied the name to any species in Asia. Basiner, 1848 (Beitr. Russ. Reich., 15:233), gives *Dolichos lubia* as one of the forage plants of Khiva, where it was known as " Lobia " or " Lobi." No description is given, and therefore its identity with Forskal's plant is not certain.

The fact that Delile says it was found also in India, but does not mention any species of Vigna, suggests that his plant may have been *Vigna unguiculata* or *Vigna catjang*. Roxburgh, 1832 (Fl. Ind., 3: 302), described *Dolichos sinensis* as with peduncles " many-flowered," and *D. catjang*, few-flowered. Baker, 1879 (Hook. Fl. Brit. Ind., 2:206), unites the two as *V. catjang* and says peduncles 3 to 6 flowered. Baker, 1871 (Oliver, Fl. Trop. Afric., 2:204), describes the racemes of *Vigna sinensis* as 6 to 12 flowered and the pods pendulous. It appears, therefore that the few-flowered character of the raceme usually observed in varieties cultivated in America is not constant in either *Vigna unguiculata* or *Vigna catjang*. The descriptions cited above indicate a variation of from 3 to 12 in the number of flowers, and the plant described by Forskal as *Dolichos lubia*, since it had erect pods, is doubtless identical with *V. catjang*. Yet, notwithstanding the variation in habit and number of flowers in the raceme, the small seeds and small, erect pods of *Vigna catjang* appear to be constant characters, and two species, *Vigna unguiculata* (*V. sinensis*) and *V. catjang*, therefore are probably concerned in the descriptions of these plants by the above authors.

It is quite possible that *Vigna unguiculata* and *V. catjang* may have been grown by the Romans without being distinguished. The cultivation and even knowledge of them, however, appears to have been extremely limited in Europe, and *V. unguiculata* at least may have first reached central Europe not from Italy, but by way of Russia and Russian Turkestan.

In 1583 Clusius (Atrebatis Rar. Stirp., 725) described and figured a plant as a kind of phaseolus which is undoubtedly *Vigna unguiculata*, though pods are not shown in the figure. Seeds of this plant were received by Clusius at Vienna in the year 1576, having been sent by Dodoens from Prague, where it was grown in the garden of the castle the previous year. The following year, 1577, seeds of the same plant were also sent by the Spaniards to the Austrian Emperor. These statements are repeated by Clusius, 1601 (Hist. Rar. Pl., p. ccxxii), where the same figure, as in the previous work, is reversed and a figure of the pods in addition is given. It would appear from these records that *Vigna unguiculata* first became known to the botanists of central and northern Europe by its being grown at Prague.

If seeds had reached Prague from Italy, the plant would probably have been known also at Vienna, which was in the route of trade from Italy northward, and, since Prague is an inland city, the seeds may have been brought overland directly from Persia or India. So long as the Venetians were in control of the trade with India, Austria and southern Germany carried on commerce with Venice. With the acquisition of the Indian trade by the Portuguese, Venice could no longer supply the markets of Europe with the products of the East and European nations apparently soon became jealous of the advantages held by Portugal, for it is stated by Robertson, 1802 (Historical Disquisition Concerning India, 319), that an attempt was made, in order to diminish the advantages which the Portuguese derived from the discovery of a sea passage around the Cape of Good Hope, to induce the Russians to convey Indian and Chinese commodities through their Empire to some port on the Baltic from which they might be distributed thróugh every part of Europe. This author also gives a brief account of the trade thus established. Yeats, 1872 (The Growth and Vicissitudes of Commerce, 155), states that Kazan was the chief entrepôt of the trade of northern and central Asia. Russian trade with other European nations appears to have been confined largely to the countries of the north and the cities belonging to the Hanseatic League. Very little seems to have been written concerning the commerce of Prague, but the Bohemians are a Slavic people and it is not improbable that they had some trade with the other Slavic peoples of Europe. At least no explanation of the occurrence of *Vigna unguiculata* at Prague before it was known at Vienna seems so plausible as that it came by one of the caravan routes to Russia and thence to Prague. De Candolle (Origin of Cultivated Plants, 39) says *Sium sisarum* " came perhaps from Siberia into Russia, and thence into Germany," and inclines to the view that it was not known to the ancient Greeks and Romans. This species is considered to be a native of the Altai region of Siberia and northern Persia. The caravan route from India and China to Russia passed through the latter region.

The figure in Rinio, 1415 (De Simplicibus), referred to by Koernicke, the writer has not seen, but in the Vienna Dioscorides Codex, dating from about the fifth century, the figure of the plant supposed to be the phasiolus of Dioscorides shows a several-flowered raceme. It also shows what appear to be mature pods and, while not strictly erect, they are not pendulous like those of *Vigna unguiculata*. The word " lubia " is written in Arabic on the parchment and the figure corresponds very closely with the description of *Dolichos lubia*. Forskal says the latter species was known among the Arabs as "*Lubia baeledi* " (common lubia). Dioscorides was probably born at Anazarba, a place in southeastern Asia Minor near the eastern extremity of the Mediterranean, but he is supposed to have traveled and it is not known where the plants he described may have been seen.

Koernicke believes the species to have come originally from central Africa, as it grows wild there. This, however, is not necessarily conclusive. There are other instances, especially in the Tropics, of plants appearing indigenous to countries in which they are known not to be native. The facts given by Koernicke indicate rather that the species has been introduced into central Africa, for he gives no name in the native language, but says it is known to the natives by the Arabian names " lubiah " and " ollaich." Seeds of this plant have never been found in the monuments of ancient Egypt, and the origin of the word " lubia " indicates that the plant to which it was applied came into Arabia and Egypt from the east. Lubia, lubiya, or lobiya probably was not derived from the Greek word λοβός, which primarily means any projection like the lobe of the ear, but appears to be of Persian origin and came to India through the Persians. Sir George Watt, 1890 (Dict. Econ. Prod. India, 3: 184), says: " No name like *lobiya* is given to any pulse by the aboriginal races of Indian or by those of Aryan origin. It occurs purely among the people of upper India, where Persian influence is most pronounced." The same author states that in all the districts of the northwest provinces, with but one possible exception, the word lobiya is applied to *Vigna catjang*.

Although none of the Indian works consulted that mention lubiya are of such ancient date as Dioscorides, they nevertheless indicate the antiquity of its cultivation in India. *Vigna catjang*, the species with erect pods, is described and figured in Rheede, 1688 (Hort. Malabar, 8: 75. *t. 41*), under the name *paeru*. It is interesting to note that the root nodules were mentioned in this work, " The root is slender, whitish, and fibrous, the fibers clothed with round globules." Rheede described nine different preparations of the seed which were used in medicine. Other bean-like plants occur in the same work under the names *putsja-paeru* and *catu-paeru*, which indicates that the paeru was better and probably longer known than the plants to which compound names were given. In a work, Ain-i-Akbari or Ayeen Akbery (Institutes of the Emperor Akbar), written in Persian during the reign of the Emperor Akbar, 1556–1605, describing the crops grown in Delhi and Agra, translated by Francis Gladwin, 1783, 1: 87, " lubya " is given as one of the crops of the autumnal harvest. Sir George Watt states that at the present time this would be *Vigna catjang*, and in all probability would have been the same in Akbar's time. Sir George Watt gives nearly 50 vernacular names in different Indian languages, of which only four are compound words and only four others consist of more than one word. One of the Sanskrit names given by Watt is *nishpáva*. In the Vishnu Purana, lib. 1, cap. 6, supposed to date from about 1045 A. D. (translation by Horace Wilson, Complete Works, 6: 95), " Nishpâva, a sort of pulse," is mentioned in the list of important grains. This work is five hundred years later than the illustration in the Vienna Dioscorides Codex. Nevertheless, Sanskrit for two thousand years or more has led an artificial existence, being the means of communication and literary expression of the priestly and learned castes, and the writer finds no indication that the name nishpâva has ever been applied to any other plant.

The species appear to be probably of less ancient cultivation in China, for there is no indication of a Chinese introduction into India or Persia, and it is improbable that the same species would be native on both sides of such a natural barrier as the Himalayas. Nevertheless, *Vigna unguiculata* at least appears to have been long cultivated in China. It is mentioned and illustrated in the second edition of the Kiu Huang Pen Ts'ao, which appeared in 1559. In this work it is called the " common bean," and other beans are compared with it. It has not been practicable to consult the first edition of this work, pubished in the beginning of the fifteenth century, and whether it ppears there or not is uncertain.

It may be noted that no plant of American origin has been identified in any Chinese work previous to the Pen Ts'ao Kang Mu, which was finished in 1578, though not published until after 1596.

It may be concluded from the facts so far known regarding these pecies that both *Vigna unguiculata* and *V. catjang* originally came from a region including and extending from India to Persia and the outhern part of the Trans-Caspian district, and that the Persians called one or both of them by the name "lubia" and applied that name to *V. unguiculata* in northwest India after their conquest of that region. The cultivation of *V. unguiculata* extended to China at a very early date, but the distribution of at least one of the species with the name "lubia" had extended from the region of its origin at the beginning of the Christian era to Arabia and Asia Minor and had reached some of the Mediterranean countries of Europe at about the same time, but did not become known in central Europe until the middle of the sixteenth century.

B. P. I.—287.

A NEW METHOD FOR THE DETERMINATION OF NICOTINE IN TOBACCO.[a]

By WIGHTMAN W. GARNER, *Scientific Assistant, Tobacco Breeding Investigations.*

THE RELATION OF NICOTINE TO THE QUALITY OF TOBACCO.

Nicotine is the characteristic alkaloid of tobacco, and thus far has not been found in any other plant. Its function in the economy of the plant is not understood, and it has not been determined with certainty whether it plays a rôle in nutrition or is simply a waste product resulting from katabolic changes in the albuminoid constituents. The physiological effects on the human system resulting from the use of tobacco are doubtless due chiefly to the presence of nicotine, though in the case of tobacco used for smoking purposes other constituents of the smoke probably play a considerable part. On the other hand, it has been repeatedly shown that the burn, flavor, aroma, and other important qualities of tobacco are in no sense proportional to the amount of nicotine present. Indeed, even the "strength" of manufactured tobacco—using this term in the sense understood by the trade—is not dependent upon the nicotine content. It seems only reasonable, however, to suppose that tobacco entirely free from nicotine would no longer prove satisfying to the consumer any more than would whisky deprived of all its alcohol.

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[a] In the Tobacco Breeding Investigations conducted by the Bureau of Plant Industry careful experiments have been undertaken to determine the relation of the nicotine content of cigar filler and wrapper tobaccos to the quality of these tobaccos. It has been found in the preliminary experiments carried out by Dr. W. W. Garner, of this office, that the nicotine content of the leaves of different tobacco plants grown under the same conditions varies in a striking manner. The variability of the nicotine content of individual plants has suggested the possibility of securing, by breeding and seed selection, strains of the different varieties of cigar wrapper and filler tobaccos possessing a low or a high nicotine content. The large number of nicotine determinations necessary in the carrying out of these tests has required a great expenditure of time and money owing to the complicated and expensive method of determination. The new method of determining the nicotine content of tobacco described in this bulletin greatly simplifies the work of the experimenter by enabling him to make many more determinations in the same length of time than by any previous method. This method also is very much less expensive than any previous method and, as shown in this bulletin, is more satisfactory from the standpoint of accuracy and reliability. The relation of the nicotine content of tobacco to the quality and other characteristics of tobacco and the possibility of breeding tobacco low or high in nicotine content will be presented in more detailed future reports of the Department.—A. D. SHAMEL, *Physiologist in Charge of Cotton and Tobacco Breeding Investigations.*

Numerous attempts have been made to devise a process for the partial removal of the nicotine from tobacco, either before or after it is manufactured, by appropriate treatment, and many patents have been issued for processes intended to accomplish this result, but none of the proposed methods has as yet proved sufficiently practicable to come into general use, and this is not surprising when it is remembered that the flavor and aroma of tobacco are comparable in delicacy to those of tea and coffee and that consequently even the mildest treatment for the removal of the alkaloid is almost certain to result in injury to these qualities.

There can be no doubt that there would be a genuine demand for tobacco containing only a very small percentage of nicotine but retaining the other attributes of the best grades of the crop as now produced, especially in the case of the cigar-filler types. The most rational method of attaining this end would seem to lie in the systematic breeding of types characterized by their low nicotine content, and at the same time avoiding those soils, fertilizers, and cultural methods which tend to the excessive production of the nitrogenous constituents of the plant. Extensive experiments have been undertaken in connection with the Tobacco Breeding Investigations of the Bureau of Plant Industry with the object of securing types of tobacco of this kind, and the results already obtained tend to show that the variation in nicotine content of individual selections from various types is fully as great as that of such physical characteristics as shape, size, and number of leaves. Since nothing like sufficient data are available for establishing any constant relation between the physical characteristics of different tobacco plants and their nicotine content, these experiments necessitate the accurate determination by analysis of the quantity of the latter in a very large number of selected plants.

THE QUANTITATIVE DETERMINATION OF NICOTINE IN TOBACCO.

In order to conduct these experiments on a sufficiently comprehensive scale it is imperative that there be available a method for the estimation of nicotine which is reasonably accurate and is at the same time rapid, so that a large number of determinations may be completed in a day's work. Kissling[a] has developed a method which seems to have given satisfactory results in the hands of most analysts, and has come to be recognized as the standard process. But this method is long and tedious, and hence is not adapted to our needs. It consists essentially in moistening the powdered sample with aqueous caustic soda and extracting with ether for several hours in a suitable form of continuous extraction apparatus. The ether is carefully distilled from the extract, and the residue is subjected to distillation with steam. The distillate is collected in 100 c. c. portions and titrated with a standard acid. It is apparent that the process is an expensive one, both in point of materials consumed and necessary equipment and in the time required for carrying it out.

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[a] Zeitschr. Analyt. Chem., XXII, 199.

Keller[a] has described a method which is simple and rapid in execution and avoids the tedious process of distilling the extracted nicotine with steam. Six grams of the tobacco, previously dried over lime, are placed in a cylinder with 60 grams of ordinary ether and 60 grams of petroleum ether, and 10 c. c. of 20 per cent aqueous caustic potash are added. The contents of the cylinder are vigorously shaken for thirty minutes and then allowed to stand for three hours to clarify. The extract is filtered and 100 grams of it placed in a cylinder. To remove the ammonia in solution, a rapid current of air is blown through the extract, after which there are added 10 c. c. of water. After shaking well, an excess of standardized hydrochloric acid is added and the titration completed with standardized ammonia. With some minor modifications the method gives fair approximations, but we have found that it is unsuited to our requirements. In point of materials consumed it is even more expensive than the Kissling process, and it also contains several sources of error. Adding 10 c. c. of aqueous potash to the ether mixture increases the total weight of solvent more than 8 per cent, and considerable quantities of nicotine remain in the aqueous portion. Ordinary ether boils at 36° C., which is but little above ordinary room temperatures, and consequently it is quite impossible to filter the extract without very considerable loss of the solvent by evaporation. Again, most tobaccos yield extracts which are so deeply colored that the nicotine can not be titrated with accuracy until the solvent has been removed. This is the principal reason why it is necessary to subject the extract obtained by the Kissling process to distillation with steam. From the results of our experiments with Keller's method, supplemented by further tests along other lines, we have developed a process which differs essentially from Keller's in all of the details of the operation and obviates the difficulties encountered in the latter.

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[a] Ber. Pharm. Gesell., 1898, 145.

Nicotine is readily soluble in nearly all of the ordinary solvents, and hence there is no difficulty in extracting it completely from tobacco after it has been liberated from its salts by means of a fixed alkali. The separation of the nicotine from ammonia and amid bodies, which are always present in tobacco, is the principal problem to be solved in this connection. By using such solvents as ether and ligroin, however, only the nicotine and a portion of the ammonia are contained in the extract, and it is possible to remove subsequently practically all of the ammonia by appropriate methods.

THE PROPOSED NEW METHOD.

In endeavoring to devise a method for estimating nicotine suited to our requirements, three principal objects were kept in mind, namely, the use of a comparatively cheap solvent, the extraction of the nicotine without the use of an extraction apparatus requiring the application of heat, and the direct titration of the extract without previous distillation. Our process as finally adopted accomplishes all of these ends, as will appear below.

Gasoline or ligroin was chosen as the most suitable solvent. This is prepared by shaking the crude gasoline of 70° with concentrated sulphuric acid and distilling and collecting the distillate coming over between the limits of 60° and 100° C. By using a product with high boiling point, the evaporation which takes place during the filtration of the extract is reduced to a minimum and there is little danger of explosions occurring from the accumulation of the vapors in the atmosphere of the room. A number of preliminary experiments were carried out to determine the conditions necessary for the complete extraction of the nicotine from the tobacco and the effect of varying amounts of ammonia on the results obtained by titration of the extracts.

PRELIMINARY EXPERIMENTS.

In order to avoid the possibility of the presence of organic acids in the extract and to insure the complete extraction of the nicotine, a fixed alkali must be added, and this is best applied in aqueous solution. Gasoline and water are immiscible and their mutual solubility is very slight, but these facts do not in any way hinder or retard the extraction of the nicotine, since the latter is easily soluble in both the water and the gasoline.

It is necessary to agitate the mixture only occasionally to avoid too great a concentration of the nicotine in the portion of either solvent which happens to be in direct contact with the tobacco. Using the ligroin in quantities of 100 c. c. to 6 or 8 grams or less of tobacco, it was found that the extraction of the nicotine is complete at the end of four hours, and when the quantity of the latter in the tobacco is small less time is required. Ligroin is capable of dissolving only a very small quantity of ammonia gas, and even this is rapidly given off when the solution is exposed to the air, and especially when it is also agitated. It was found by experiment that 100 c. c. of ligroin saturated with ammonia, after being allowed to stand one hour in an unstoppered Erlenmeyer flask, retained less than 5 milligrams of this base. On the other hand we have found that no loss of nicotine whatever occurs when a solution of 0.3 gram of the base in 100 c. c. of ligroin—equivalent to 5 per cent nicotine in 6 grams of tobacco—is allowed to stand several hours in an open beaker at ordinary room temperature. Tobacco, especially after it has been fermented, contains considerable quantities of ammonia, but it was found that only a small proportion of this is contained in the extract; hence the quantity dissolved is not sensibly affected by the varying amounts contained in different samples of tobacco.

This fact is of importance, because it renders the subsequent removal of the ammonia a very simple matter; in fact, even if no attempt is made to remove the ammonia in solution the error resulting therefrom will not exceed 0.2 per cent. In the following table the results given in percentages in column 1 were obtained without the previous addition of ammonia, while those in column 2 were obtained from the same samples after the addition of quantities of ammonia in aqueous solution corresponding to 1.4 and 3.5 per cent, respectively, for 6 grams of tobacco:

Field number of tobacco samples.	1 Nicotine.	2 Nicotine.
	Per cent.	*Per cent.*
13-2-3	3.51	3.53
3-20-2	3.04	3.05

A fair idea of the ammonia actually dissolved by the gasoline is given by the results shown in the following table. The percentages in column 1 were obtained by direct titration of the extracts, while in the case of the first two experiments, the results of which appear in column 2, a current of air was drawn through the extract for five minutes before titrating, and in the last three experiments the solutions were allowed to stand an hour in unstoppered Erlenmeyer flasks before making the titrations.

Field number of tobacco samples.	1 Nicotine.	2 Nicotine.
	Per cent.	*Per cent.*
13-2-3	3.53	3.46
3-20-2	3.09	3.04
123a-1-4	1.92	1.82
123a-1-2	1.86	1.76
3-20-5-12	1.53	1.72

Finally, a number of analyses of different samples were made in duplicate to show that the proposed method gives concordant results even when some of the conditions are somewhat modified, as, for example, when the volume of aqueous caustic soda added to the tobacco before extraction is varied. The tabulated results follow:

Field number of tobacco samples.	1 Nicotine.	2 Nicotine.
	Per cent.	*Per cent.*
75–124, 222	4.90	4.9
75–124, 202	3.92	3.9
125a–1–2	2.00	2.0
123a–1–1	1.95	1.9
123a–1–3	1.88	1.8

DESCRIPTION OF THE METHOD.

From these preliminary data we have been able to work out the details of a very simple method for the quantitative estimation of nicotine which is both rapid and accurate and requires nothing but the simplest forms of apparatus and inexpensive materials.

The air-dried sample is pulverized by passing through a sieve containing twenty or more wires to the inch. For exact work the water content is determined by drying over sulphuric acid for forty-eight hours 1 gram of the sample on a large watch glass placed in a desiccator, while for approximate results the air-dried sample may be assumed to contain 5 per cent of water. Six grams of the pulverized sample are weighed into a beaker, from 3 c. c. to 5 c. c. of 5 per cent aqueous caustic soda solution are added, and the mixture is stirred with a steel spatula until homogeneous. The quantity of caustic soda solution to be used depends on the character of the tobacco to be analyzed; thin, light-bodied samples, such as cigar-wrapper tobaccos, require a larger amount of the solution than do thick, heavy samples, such as domestic cigar-filler types.

The moistened sample is next transferred to a 200 c. c. glass cylinder and 100 c. c. of the ligroin are added. The cylinder is tightly stoppered and the contents thoroughly agitated for a few minutes, after which the cylinder is placed in a horizontal position. This insures the exposure of a maximum amount of surface of the tobacco to the solvent action of the ligroin. Stout glass tubing of suitable diameter and length, sealed at one end and fitted with a good soft cork, serves equally as well as the cylinder for the extraction. After four hours, during which time the contents of the cylinder should be thoroughly agitated at intervals of about thirty minutes, the latter is placed in an upright position in order to allow the upper portion of the gasoline to clarify. After thirty minutes or longer the extract is passed through a folded filter, care being taken to first moisten the filter with the clear portion of the gasoline. The extract is poured off from the tobacco without bringing the latter on the filter, and further portions are pressed out by means of a glass rod flattened at one end. The filtration should be carried out as rapidly as possible in order to avoid loss from evaporation, and as soon as all the extract can be brought on the filter the funnel should be covered with a watch glass. An aliquot portion of the filtrate—conveniently 75 c. c., corresponding to 4.5 grams of tobacco—is measured into a dry separatory funnel, which is left unstoppered and allowed to stand for about an hour in order to remove the ammonia. As has already been stated, no loss of nicotine is to be feared by this treatment. Instead of allowing the extract to stand in the funnel a slow current of air may be drawn through it for five minutes by means of a stopper supplied with inlet and outlet tubes, the latter of which is connected with a filter pump. After the ammonia has been removed 10 c. c. of fifth-normal sulphuric acid in about 50 c. c. of water are introduced into the funnel and the contents thoroughly shaken. After drawing off the aqueous layer the gasoline is washed twice with small volumes of water and the excess of sulphuric acid titrated with tenth-normal alkali, using cochineal as the indicator.

This method of titrating the nicotine may be modified as follows: The measured portion of the filtered extract is placed in a 250 c. c. Erlenmeyer flask and allowed to stand an hour. The standard acid is then run in and a convenient volume of water added. The contents of the flask are thoroughly shaken, and after the two layers have separated the greater portion of the ligroin is drawn off by means of a pipette.[a] The excess of acid is then titrated as before. One cubic centimeter of fifth-normal sulphuric acid is equivalent to 0.0324 gram of nicotine.

COMPARISON OF THE NEW METHOD WITH THAT OF KISSLING.

As has already been stated, the only reliable method for the determination of nicotine heretofore available is that of Kissling, and we have used this as the standard for comparison. The nicotine content of a large number of samples of tobacco of different types has been determined both by the Kissling process and by the new method, and the figures given in the following table are fairly representative of the results obtained.

It will be seen that the nicotine content in the different samples included in the table varies from 5 to less than 1 per cent, and these samples represent practically all classes of domestic cigar tobacco of both wrapper and filler types. Most of the samples had been fermented, but some of them were unfermented. All results are calculated on the water-free samples.

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[a] It is necessary to remove the greater portion of the gasoline before titrating because of the yellow coloring matter which it contains in solution.

Field number of tobacco samples.	Kissling method.	New method.	Difference.
	Per cent.	*Per cent.*	*Per cent.*
75-154, 242	5.03	5.02	−0.01
75-154, 218	4.70	4.61	− .09
13-2-3	3.66	3.57	− .09
3-20-2	3.18	3.09	− .09
125b-1-4	2.60	2.59	− .01
123a-1-12	2.37	2.27	− .10
124b-1-1	2.19	2.11	− .08
123a-1-14	2.15	2.08	− .07
125a-1-2	2.19	2.03	− .16
123a-1-1	2.00	1.92	− .08
125b-1-1	1.92	1.95	+ .03
123a-1-8	1.97	1.88	− .09
123a-1-3	1.96	1.87	− .09
123a-1-2	1.72	1.76	+ .04
123a-1-9	1.64	1.77	+ .13
125a-1-4	1.64	1.57	− .07
3-20-5-12	1.52	1.53	+ .01
124b-1-6	1.58	1.49	− .09
3-20-5-6	1.32	1.40	+ .08
109-3-4	.89	.94	+ .05

Average difference, 0.04 per cent.

CONCLUSION.

It will be observed that the results shown in the above table indicate that the new method gives figures averaging a few hundredths per cent lower than the Kissling method. This difference is due to the water added to the sample along with the caustic soda, which is not taken into account in the calculations. From 3 to 5 c. c. of water are thus added, depending upon the character of the tobacco. As is well known, tobacco is markedly hygroscopic, and a considerable portion of the added water is doubtless held in loose chemical combination with the salts contained in the tobacco, and hence does not act as a solvent for the nicotine. The portion of the water not thus combined, however, really forms a part of the nicotine extract. It was found by experiment that the relative solubility of nicotine in ligroin and in water is in the ratio of 11 to 9. The mutual solubilities of ligroin and water are so slight as to be negligible, and there is no appreciable contraction in volume when the two are mixed. Taking all the facts into consideration, it is clear that the actual error resulting from the addition of the water to the sample to be analyzed is too small and variable to attempt any correction therefor.

It should be observed in this connection that those types which contain the highest percentage of nicotine belong to the class of heavy filler tobaccos, and hence require the addition of only the smallest quantity of water. This, of course, tends to equalize this source of error. The analyses by the Kissling method were not made in duplicate, and differences in the results obtained by the two methods amounting to one-tenth of 1 per cent or more are doubtless due to slight experimental errors.

After a very careful test of our new process, we are fully convinced that it gives very reliable and accurate results, while it is so simple in execution that there are few chances for the occurrence of errors in manipulation.

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